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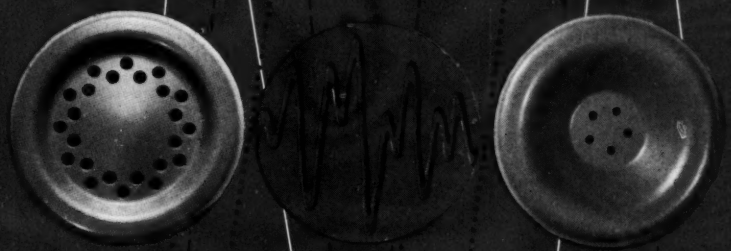
GENERAL TELEPHONE TECHNICAL JOURNAL



GENERAL SYSTEM

JULY, 1959 VOL. 6, NO. 5

GENERAL TELEPHONE TECHNICAL JOURNAL

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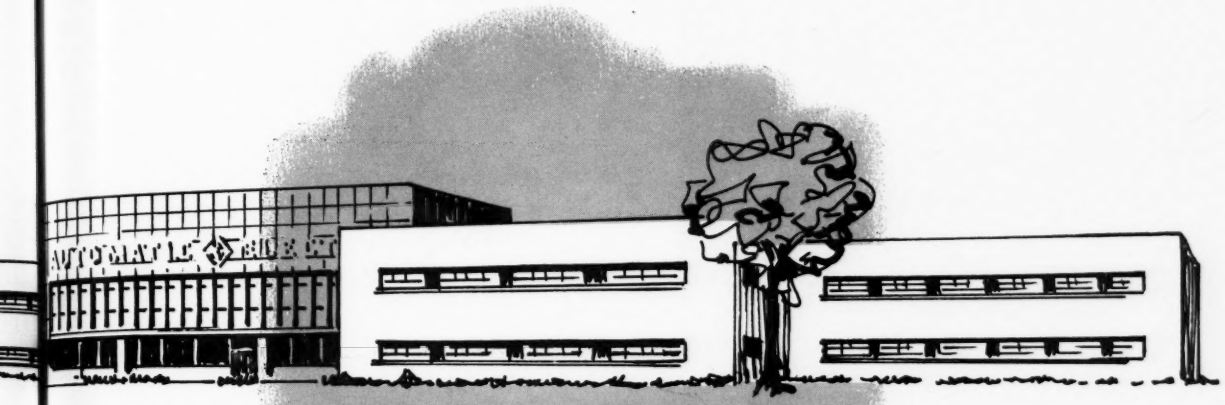


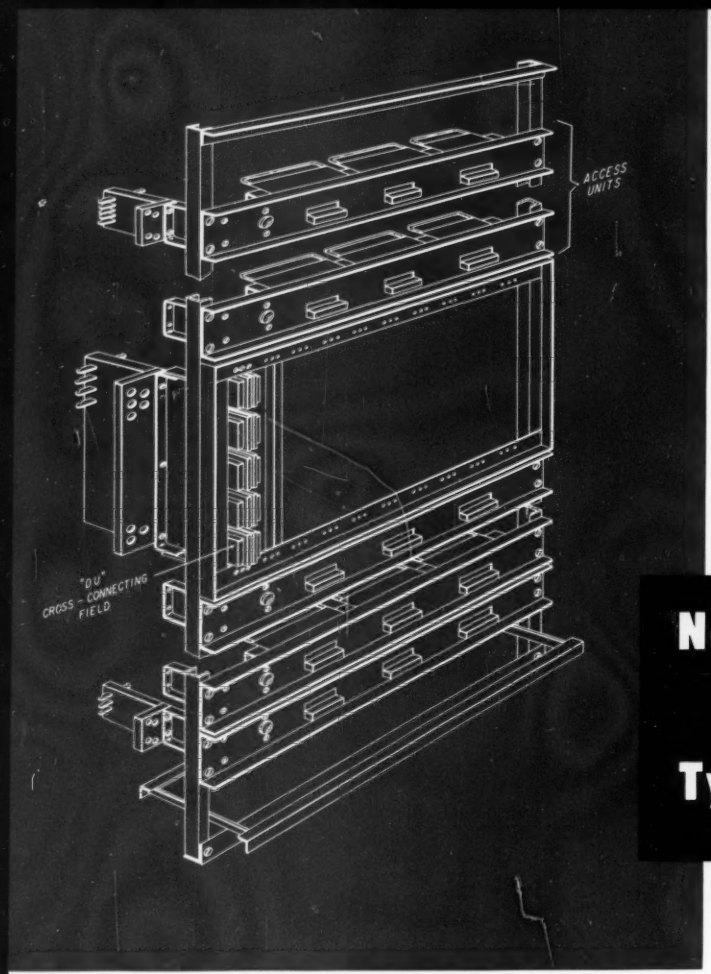
We are publishing, in this issue of the Journal, two Conference Papers which were presented in June at the Summer and Pacific General Meeting of AIEE, by members of our Laboratories staff. Some of our readers will doubtless have heard these papers read at that time; if you are one of these, you will be glad to have them in this permanent form, and we feel sure you will understand our desire to bring them to other telephone people.

• • •

In automatic ticketing of toll calls, the information that involves the most complexity to obtain is the number of the *calling* party. The new Type 59 Detector uses novel circuit and mechanical arrangements in order to provide this information economically to the ticketing equipment in frequency-per-terminal offices, both large and small, having up to ten parties per line.

• • •

With the development of three automatic routiners described in this issue, automation has taken a few more steps in its onward march. These machines, installed in exchanges equipped with Type "A" SATT equipment, will put the basic SATT units through their paces under properly controlled conditions, and report their findings, so that operating companies may be sure their equipment is free of incipient faults that might affect service.



New Versatile Detector *for* Type 59 SATT Systems

By R. O. Stoehr and B. Sherstiuk

Figure 1. Type 59 SATT Detector

For automatic ticketing of toll calls, the one item of information which is not readily available on each call is the number of the *calling* party. The *called* number is derived from the pulses dialed; the date and time of the call, and its length, are easily determined by a timing device; but automatic identification of the calling party is a problem which has required extensive study and development.

The problem has been by-passed, in some systems, by having the calling subscriber dial *his own* number; this is called "Dialed Number Identification" (DNI). Normally, verification facilities are then provided, to prevent dishonesty. In other systems, an operator enters the connection to request the number of the calling party, and "keys" it into the ticketing storage equipment; this is called "Checking Operator" (CKO) operation.

The ultimate method of identification, however, is "Automatic Number Identification" (ANI), which uses an automatic unit to identify and record the number of the calling party without any conscious action on his part. In Type "A" SATT offices (frequency per group), the equipment on each line comprises only a pair of relay springs, a neon lamp, and a resistor. In Type "B" and "BD" SATT offices (frequency per terminal) detection has been accomplished by means of Detrel relays, one of which must be assigned to each station.

The Type 59 SATT Detector (Figure 1) described in this article, was developed to provide, in frequency-per-terminal offices, the advantages of the frequency-per-group Detector used in the largest Type "A" SATT systems. It provides automatic detection, economically, for frequency-per-terminal offices, large and small, having up to ten parties per line.

Detection of a calling station is carried on through the control lead of the established connection. Since this lead is also used for busy testing,

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and for holding the switch train, the signal employed for automatic number identification must, of course, be different from the potentials (exchange battery and ground) normally appearing on the control lead—and must not interfere with its functions. In SATT systems, this signal is provided by +60v. battery, which, when added to the 50v. exchange battery, provides a firing voltage for a neon lamp, and subsequently actuates the marking device.

Party Lines — TPL and TPS

Party lines present a problem. For universal application the Detector should be able to serve terminal-per-line (TPL) as well as terminal-per-station (TPS) lines. Under the TPL plan, all stations of a party line are assigned to the same connector terminal; their directory numbers differ in only one digit (which corresponds to the station number of the subscriber). The Detector need only identify the line; the station number is identified thru the Ticketer.

Under the TPS system, each station on a party line is assigned an individual connector terminal; thus, the directory numbers of the stations on the same line may differ widely. It is therefore necessary that each station be equipped for individual detection. Also, since the control lead of a party line is common to all stations, signals on the control lead will appear on all control-lead connector terminals associated with this line. This requires that the Detector complete the circuit to the identification equipment of the calling station *only*.

The TPS system may be either "frequency per group," or "frequency per terminal." In frequency-per-group offices, each connector serves only one group of stations (such as those with 25-cycle ringers). Since the specific party on the calling line is identified by the Ticketer, the Detector can be made to recognize signals only in the connector groups which serve these parties. In frequency-per-terminal offices, on the other hand, no connector station grouping exists; the Detrel Detector, which has been used in such offices, requires the addition of a relay per terminal. The new Type 59 SATT Detector can use relatively inexpensive terminal equipment similar to that of the Type "A" Detector, but will also provide service for frequency-per-terminal offices.

Design

It is apparent that if the Detector is to be universally applied, it must have considerable inherent flexibility. For this reason it is divided into its basic components, which can be combined to provide the facilities or features required in any specific case. For such universal application, the basic unit must be small enough for the smaller office, but not so small that excessive duplication would be required in the larger office. Too large a unit would require profuse multiple wiring; for example, if one common cross-connecting field were made to provide the full complement of 10,000 terminals, it would have to be used also for an office of 1500 terminals. On the other hand, a smaller field would lend itself more readily to expansion, and would not involve a large initial outlay on each installation. It was therefore decided that the basic unit would have a capacity of 3,000 terminals.

Since the Detector lends itself to logical subdivision, it is constructed as two distinct units as illustrated in Figure 1:

The Access Unit, which contains all the individual terminal equipment, including the "MC" (thousands and hundreds) Cross-connecting Field associated with each connector hundred-group.

The "DU" *(tens and units) Cross-connecting Field,* designed to be common to all Access Units. Since the basic unit is 3,000 terminals, the DU Field also has this number of terminals, and is an integral part of thirty 100-terminal units of access equipment.

The rack layout is designed so that the 3,000 terminal DU field is mounted near the center of the equipment rack, with as many as 30 units of access equipment mounted above and below. For very small offices, it should be possible to provide 2,000 terminals on a rack 9 feet high.

To apply these principles, within the limits of cost and size that we had set for ourselves, we have used printed-wiring boards for the individual equipment units, and have interconnected them with their associated MC fields by means of patching leads with "Taper Tab" terminals. These mechanical terminals provide connections which are very firm yet can be quite readily changed; they require no soldering.

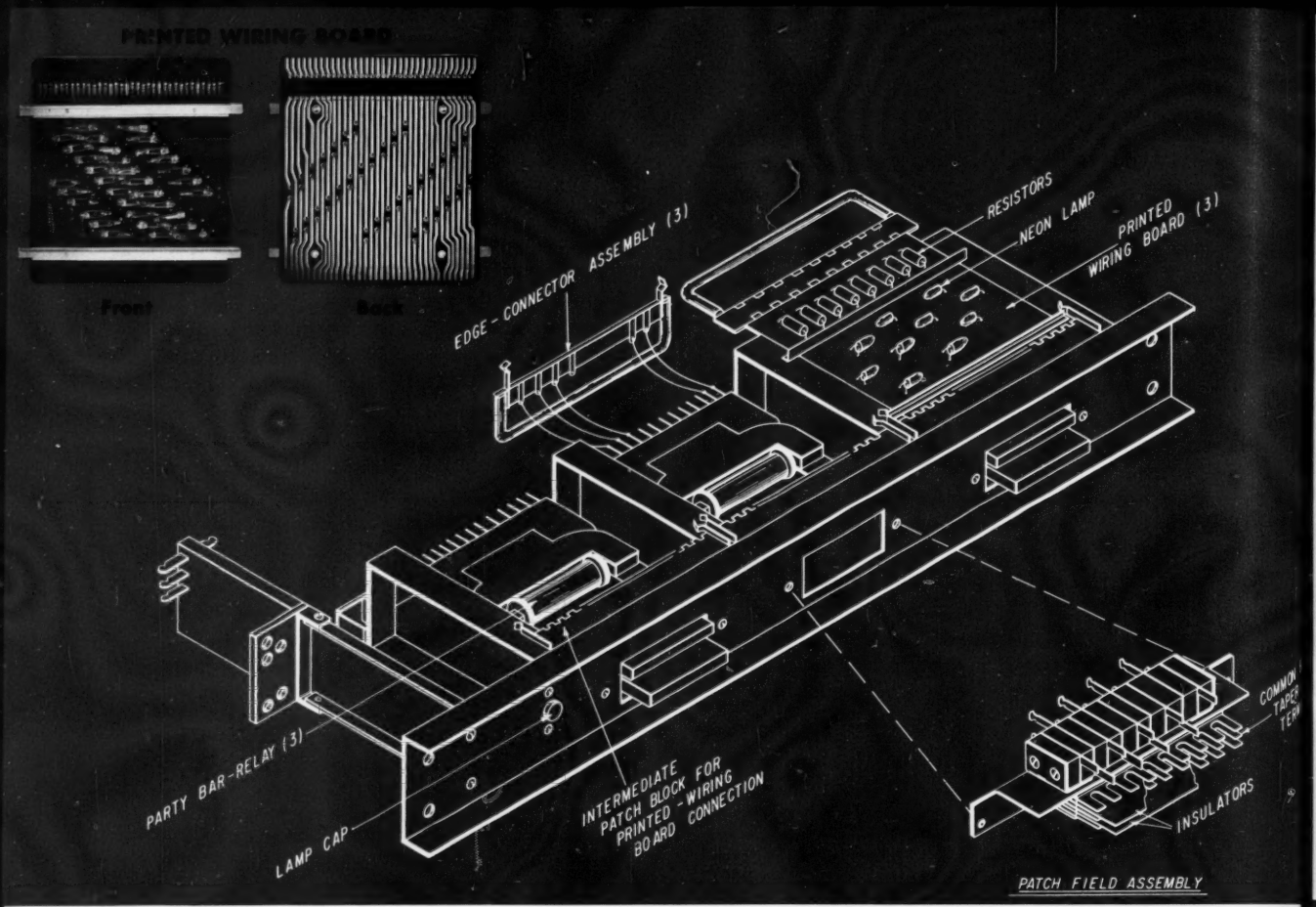


Figure 2. Detector Access Equipment and Printed Wiring Board

Detector Access Unit (Figure 2)

Access Units are designed around the Automatic Electric Bar-relay, which has 35 pairs of springs. One pair of springs is assigned to each party; thus, three party Bar-relays, side by side, form the basis of an Access Unit serving a connector hundred-line group. Associated with each relay is a printed-wiring board, an intermediate patch-block, and an MC patch-field assembly.

The printed-wiring boards are interchangeable, plug-in-units, each containing 34 neon lamps and 34 resistors. The resistors are fastened directly to the board, while the lamps are mounted on stand-off terminals to permit easy replacement of the lamps without the necessity of unsoldering the lamp leads from the printed board. Each printed-wiring board is inserted from the rear of the Unit; it is plugged into the intermediate patch-block directly over the associated party Bar-relay, and rests on the relay mounting. Connections between the relay and the board are made by means of a handle assembly containing an "edge-connector" that engages terminals on the rear edge of the board. This connector also carries the installer's wiring from the LIDF.

The MC patch field consists of a series of common buses, each containing 16 Taper-Tab terminals. As many of these buses are assembled into a field as may be required for a particular office; for example, a four-party office would require a bus for each party, a "no-detect" bus, a party "O" bus, and a spare—a total of seven buses, which are separated by clear plastic insulators, designed to prevent shorting of the patch cords on adjacent buses.

Each terminal of the intermediate block (except for those necessary to provide outgoing leads for the MC patch field) represents a particular station, which must be connected to the proper party-bus of the MC field. To minimize errors in making these connections, patch cords of different colors are used for the different parties (and for the MC field outgoing leads); e.g., if blue represents party 1, all connections to the party 1 bus will be made by

means of blue patch-cords. The design of this Access Unit permits high equipment density, thus saving valuable space.

DU Cross-connecting Fields (Figure 3)

The "DU" field is an assembly of one hundred patching-blocks—twenty vertical rows of five each. Each block consists of a number of individual terminals and a small common patch field, similar to the MC patch field. Each of the common buses of the patch field represents a party, and as many of these buses are provided as required.

Each patching block represents a particular connector terminal of the one-hundred group (hence, there are 100 patching blocks). Referring to the DU illustration, Figure 3, the upper left-hand patching-block represents terminal 11 of all the access equipments associated with that particular DU field. The next block below represents terminal 12 of all the units, and so on down and across the field for a total of one-hundred blocks.

The unique design of the DU field makes it readily accessible for necessary changes as they arise. Changes are easily made, because each terminal and party is plainly identified, and the Taper-Tab patch-cords need simply be moved to the proper terminals—without use of a soldering iron. Plastic ducts for wiring eliminate the necessity of untying and replacing cables, and assure a neat-appearing unit, regardless of the number of cable additions.

Ease of Installation

For initial installation, the equipment is completely wired, and all equipment (except for the printed-wiring boards) is assembled. The installer need only provide the multiple cables between DU fields on adjacent racks, the cables from the MC and DU Party Bar-relays, the access cables from the LIDF, and the miscellaneous power and signal cables. All installer cables terminate on terminal blocks—no wiring to relays or patching-blocks is required. The printed wiring boards are shipped separately, and are inserted into the access equipments after the cabling has been completed.

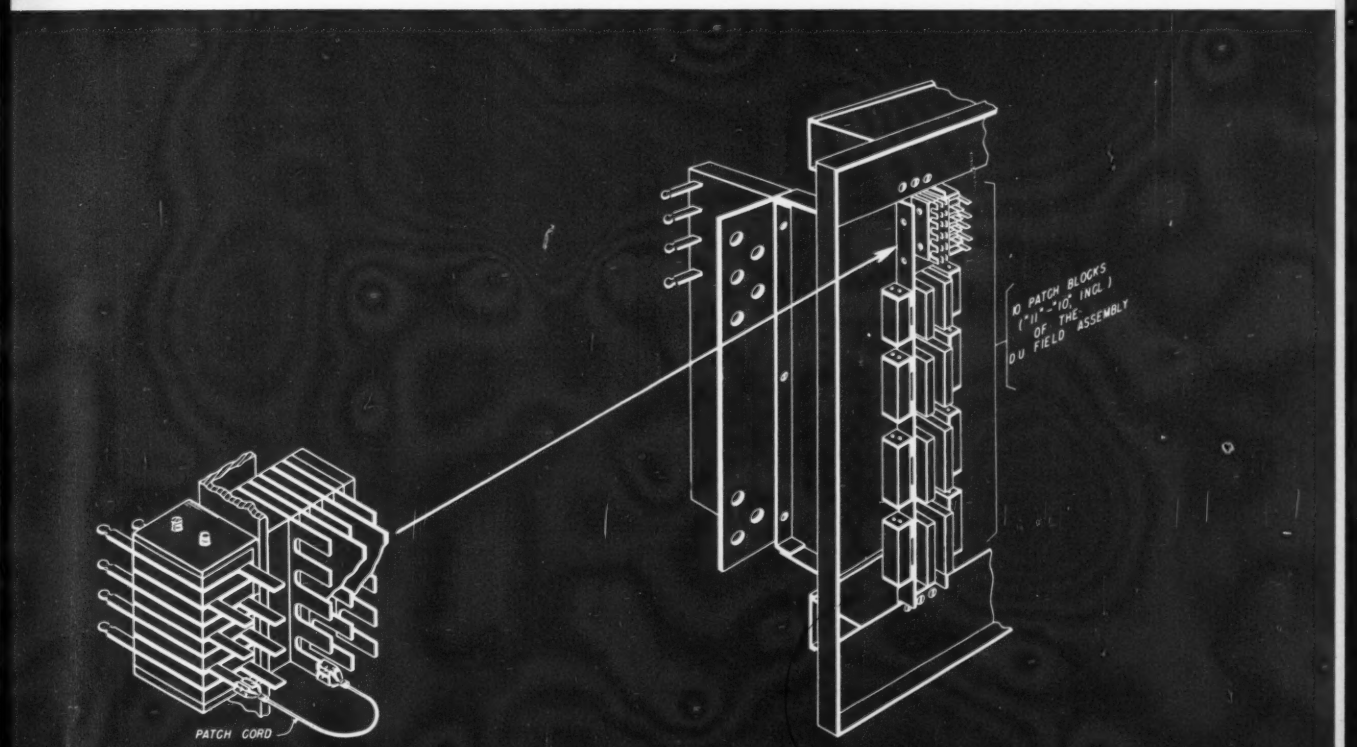


Figure 3. DU Cross-connecting Fields

Each Access Unit is connected to the "DU" cross-connecting field on the same rack by means of a 100-conductor, color-coded, plastic cable. Terminal 11 of each Access Unit is cabled to a terminal in patching-block 11; terminal 12 is cabled to a terminal in 12, etc. Thus, the same terminal number on every Access Unit is represented as an individual terminal within the same patching-block; or, all terminals 11 of all Access Units are represented on one patching-block known as block 11, all terminals 12 of all Access Units are represented on another block known as block 12, etc.

Patching between the individual terminals and the party buses in any one patching-block is accomplished with colored patch cords, as on the Access Units.

Party-Identity Relay Circuits (Figure 4)

Each party group in the office will require one party relay to recognize party marking provided by the Ticketer, at least one MC party Bar-relay to associate the respective MC party buses with MC register relay circuits, and at least one set of three DU relays to associate the respective DU party buses with D and U register relay circuits. Each contact of the MC party Bar-relay is connected to its respective party bus in different access groups. Since 35 contacts are available on the MC party Bar-relays, one relay can serve 35 access groups. If the Detector is to serve more than 35 connector groups, additional MC party Bar-relays can be provided, as required.

Digit-Register Relays Circuits

MC and Office Code Register Relays (Figure 5)

When +60v battery is connected to a control lead, 110 volts is impressed across the neon lamp, the series resistor and the MC relay circuit. With most of the voltage dropped across the resistor and lamp, the remaining voltage is not sufficient to operate a standard relay.

The Type "A" SATT Detector uses a sensitive relay for this purpose, but this relay is quite costly. In the Type 59 Detector we have used the NPN general-purpose type transistor, which is well suited for this application, and compares very favorably in cost. It has a 30v absolute maximum collector-to-emitter voltage rating; to provide current within this voltage limit, a Zener diode is provided, to derive 28v ± 5% from the standard exchange battery as shown in Figure 9 (page 152).

Diode D1 is provided to protect the transistor from negative surges on the control lead. Diode D2 protects the transistor from inductive surges from

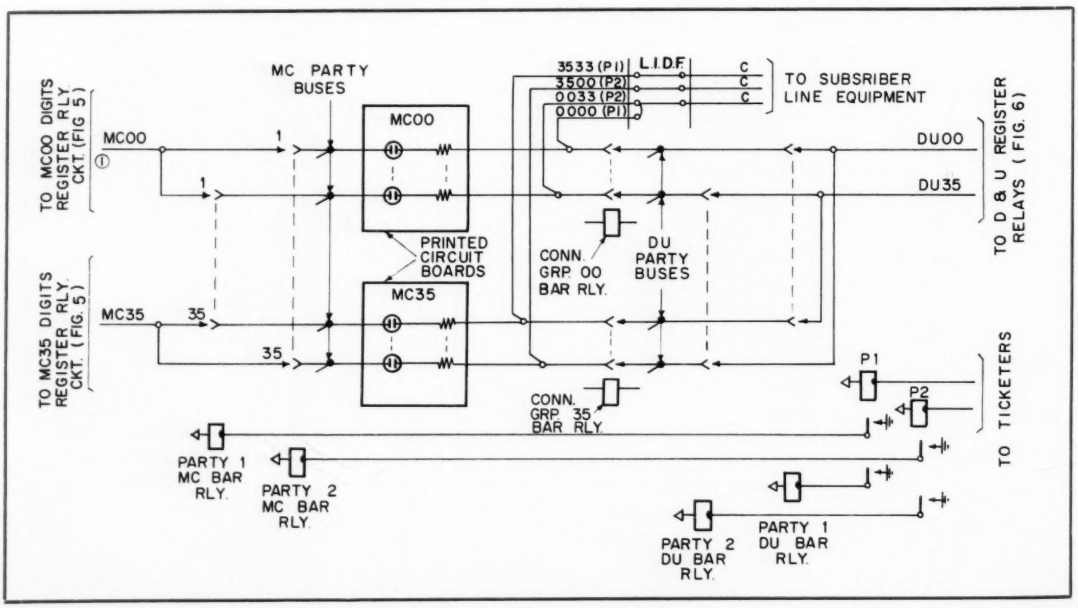


Figure 4. Party-Identity Relay Circuits

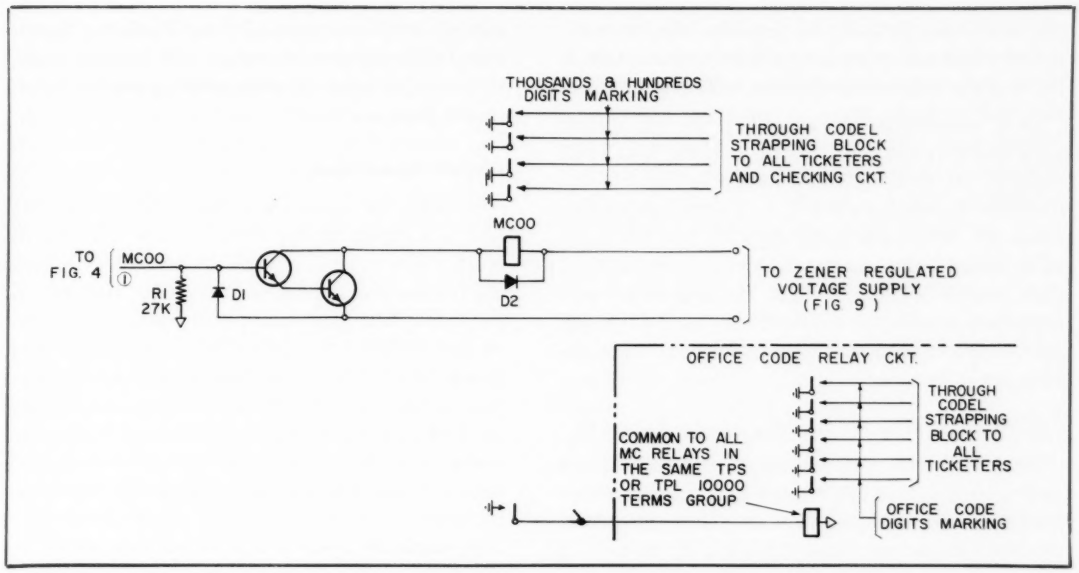

THOUSANDS & HUNDREDS DIGITS MARKING
THROUGH CODEL STRAPPING BLOCK TO ALL TICKETERS AND CHECKING CKT.
MC00
TO FIG. 4
MC00
R1 27K
D1
D2
TO ZENER REGULATED VOLTAGE SUPPLY (FIG 9)
OFFICE CODE RELAY CKT.
THROUGH CODEL STRAPPING BLOCK TO ALL TICKETERS
COMMON TO ALL MC RELAYS IN THE SAME TPS OR TPL 10000 TERMS GROUP
OFFICE CODE DIGITS MARKING

Figure 5. MC and Office Code Register Relays Circuits

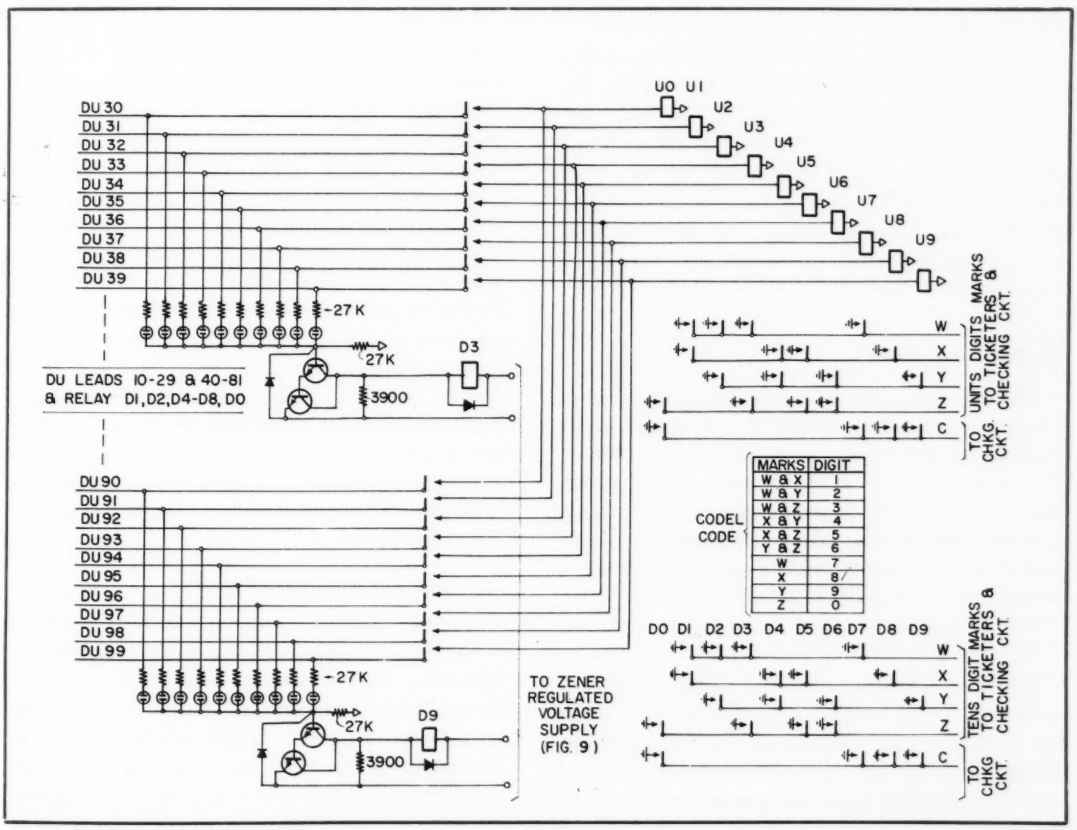


Figure 6. D and U Register Relays Circuits

the MC relay. Resistor R1 provides bias for transistors which are in a non-conductive state; thus it limits their collector-to-emitter leakage.

In a terminal-per-station office, the office-code relay registers the ABC digits, and the MC relay registers the thousands and hundreds digits of the directory number. However, in a terminal-per-line office the office-code relay registers the AB digits of the office code, and the MC relay registers the C digit and the thousands digit. MC and office-code relays are provided as required, i.e., one MC circuit per connector group, and one office-code relay circuit per office code.

"D" and "U" Register Relays Circuits (Figure 6)

Each "D" relay is connected through neon lamps and resistors to ten DU leads which have common tens digits (the lamps and resistors are, of course, provided to prevent control leads from being tied together). The D-digit register-relay circuit is the same as the MC register-relay circuit, except for the 3900-ohm resistor which is provided to pre-energize the relay and thus speed up its operation.

In terminal-per-station and terminal-per-line "frequency first" offices, the "D" relay registers the tens digit of the directory number, and the "U" relay registers the units digit. In terminal-per-station "frequency last" offices, the "D" and "U" relays register the hundreds and tens digits of the directory number, respectively. "D" and "U" relays are part of the office common equipment and only one set of each is normally provided.

Control Equipment

The control equipment provides the following facilities: overall time-out of the detection cycle, Zener-regulated voltage supply for the transistors, "2 out of 5" checking circuit for terminal digits, and controls for the Detector battery supply; busy and idle Detector markings; "complete-," "incomplete-" and "no-detection" markings, peg-count meters, alarm circuits, etc.

Supervisory Facilities (Figure 8)

Supervisory facilities consist of terminal-digits supervisory, connector-group supervisory, and alarm lamp circuits. Each neon lamp and resistor in the connector-group supervisory circuit is associated with a particular connector group. In operation, the neon lamp associated with the connector group will light. If a fault occurs, the lamp will remain lighted, subject to manual reset. Similarly, the terminal-digit supervisory circuit will provide indication as to the terminal-digit marking involved at the time a fault occurred.

Circuit Operation

Basically the operation is simple. When the Ticketer is assigned to the Detector, the Ticketer extends a party marking to the Detector and switches the control lead from ground to +60v battery. The respective MC party Bar-relays operate, and close all MC register-relay circuits to the particular party group buses. The +60v battery is extended over the control lead of the switch train and through the LIDF to the terminals of the neon lamps associated with the calling line. The neon lamp connected to the MC register-relay circuit "fires" and becomes conductive. The MC register relay operates, marks the thousands and hundreds digits, and closes the circuit to its associated connector-group Bar-relays, and to the office-code relay. The office-code relay operates and marks the office-code digits.

Approximately at the same time as the MC party Bar-relay operates, the DU party Bar-relay also operates, and connects all DU leads to the DU party buses associated with the respective party group. When the connector-group Bar-relays operate, +60v battery appears on the DU lead which represents the last two digits of the directory number of the calling subscriber; this "fires" the neon lamp associated with that DU lead. The D relay operates, marks the tens digit, and switches the DU lead in its group to the U relay. The U relay operates from +60v on lead DU, and marks the units digit; all digits have now been registered. Unless faulty marking is recognized by the terminal-digit checking relays, a "complete detection" mark is sent to the Ticketer, causing it to release the Detector. The Detector can now serve another Ticketer; the whole cycle has been completed in some 300 milliseconds.

Detection Cycle (Figure 7)

The detection cycle can be best described by an illustration. For this purpose let us assume that the subscriber whose directory number is AR6-0033 (i.e., 276-0033) and who has Party No. 2 telephone on a 2-party line, is making a call. Figure 7 shows the essential parts of the equipment involved in the identification of this subscriber's directory number.

While the subscriber is dialing the first digit (or first two digits) into the Ticketer (the reference is

primarily to the Type 59 Ticketer, but the description in general also applies to equivalent Ticketers, and to outgoing trunks), the Ticketer identifies the calling subscriber as having Party No. 2 telephone. Switch PS will be on the second bank contact, and will remain there while the detection cycle is completed. After the second digit has been dialed into the Ticketer, it calls for assignment to the Detector by operating the KA relay. Only one Ticketer can be assigned to the Detector at one time, but since the detection cycle is very fast, delays of even a few seconds will be rare even in the largest offices.

When the Ticketer has been assigned, the circuit is completed between its KB relay and the Detector KA relay. The KA relay operates, opens the first timing relay, and closes the 28v Zener-diode-regulated supply to all MC and D register-relay circuits (Figure 9). Relay KB in the Ticketer operates, closing the circuit to the Ticketer Bar-relay and relay KD. KD operates, and transfers the control lead from ground to +60v battery. The Ticketer Bar-relay operates, extends ground over lead P2 to Party No. 2 relays (Figure 4), and extends the Detector common leads into the Ticketer circuit. Relay P2 operates and closes the circuit to Party No. 2 MC Bar-relays and Party No. 2 DU Bar-relays. Party No. 2 MC Bar-relays operate, and close all MC party buses serving Party No. 2 MC register-relay circuits (Figure 5). Party No. 2 DU Bar-relays operate, and close all DU party buses serving Parties No. 2 to the "D" and "U" register-relay circuits (Figure 6). The +60v battery on the control lead holds the switch-train, marks the switches and the Ticketer busy, and finds its path through the LIDF to the terminals of the neon lamps serving the two subscribers on the line.

Since Party No. 1 MC Bar-relay is not operated, the path through the neon lamp serving Party No. 1 (276-0000) terminates at its contacts. The path through the neon lamp serving Party No. 2 (276-0033) is extended through the operated contacts of Party No. 2 MC Bar-relay to the exchange battery (—50 v.) in the MC00 relay circuit. With 110v. impressed across the lamp (in the non-conducting state the neon lamp has very high resistance, so for practical purposes the whole voltage drop may be considered to be across the lamp), the lamp "fires," and becomes conductive.

Referring to Figure 5, it will be noted that the base of each transistor is connected through an individual resistor to the negative terminal of the exchange battery. The bases are therefore normally at exchange battery potential. Approximately two volts are dropped across resistor R1 (15 ohms); thus the potential normally appearing at the emitters of the transistors is approximately two volts less negative than that at the bases. This provides a reverse bias for the transistors, which considerably reduces the leakage when 28 v. is applied between the collectors and emitters of all transistors.

When the neon lamp serving subscriber 276-0033 "fires," the bases of the transistors of MC00 relay circuit become sufficiently more positive than their emitters to switch the transistors from their non-conductive state. The transistors conduct, and the circuit is established through relay MC00. The MC00 relay operates, marks the thousands and hundreds digits to the Ticketer, closes the circuit to the connector-group Bar-relays and to the office-code relay, and closes 160 v. across its associated neon lamp in the connector-group supervisory circuit (Figure 8). The office-code relay operates and marks the office-code digit (276) to the Ticketer. The neon lamps require 135 v. ± 15% to "fire;" with 160 v. across it, the neon lamp serving connector group 00 "fires" and becomes conductive; this indicates that detection is taking place in that connector group. The connector-group Bar-relays operate, and connect all leads in their group to the DU party buses.

Similarly, on the DU side of the circuit, +60v. battery on Party No. 1 subscriber's lead will terminate at the contact of unoperated Party No. 1 DU Bar-relay. The +60 v. battery on the subscriber's lead of Party No. 2 (276-0033) is extended through operated Party No. 2 DU Bar-relay and appears on lead DU33 (Figure 6). The neon lamp associated with lead DU33 becomes conductive. The D3 relay operates in the same manner as described for the MC00 relay; when operated, it marks the tens digit (3) to the Ticketer, and closes all DU leads in its group to U relays. The 110 volts appears across U3 relay; it operates and marks the units digit to the Ticketer. (It may be noted here that ground potential may be present at this time on other DU leads in the D3 relay group, but the U relays will not operate on 50 v.).

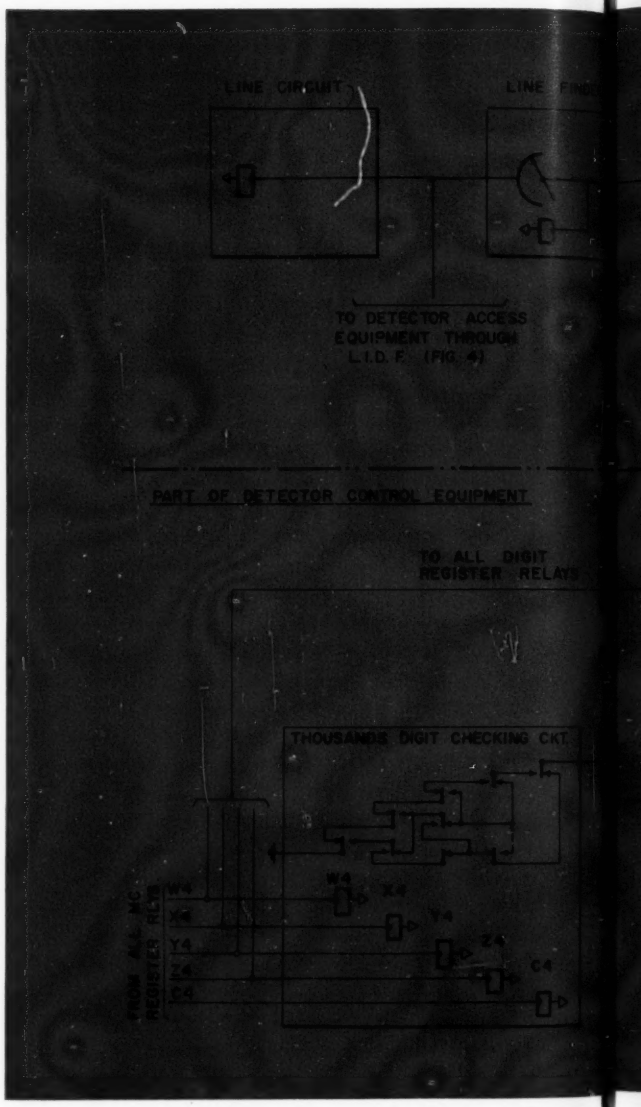
Terminal Digits Check

All digits are transmitted to the Ticketer in the codel (binary-decimal) code shown in Figure 6. To accommodate the "2 out of 5" check, all relays that register single-mark terminal digits are arranged to provide also a second mark (which is

not extended out of the Detector but terminates in the respective digit-checking relay circuit). When the digits are marked to the Ticketer, a multiple connection is also made to the checking-relay circuits. The digit-checking relay groups are arranged in sequence (thousands, hundreds, tens, and units digits groups, in that order) so that the input to a succeeding group is completed only if a satisfactory check has been made in the preceding digit-checking relay group or groups. The checking relays, when operated, also close 160 v. across their associated lamps in the terminal-digits supervisory circuit. The neon lamps light and indicate the detected terminal digit. When a satisfactory check has been made for all digits, the circuit is closed to relay CD, which operates, indicates to the Ticketer that the detection cycle has been satisfactorily completed, and closes relay KG. Relay KG operates, locks to multiple-operated relay circuits in the Detector, and opens the short-circuit on the resistor in series with the Detector KA relay. The Ticketer releases the connection to the Detector, but the Detector cannot be re-assigned until relay KG is released and the short is replaced on the series resistor.

Incomplete Detection

As mentioned above, when the Detector KA relay operates, the circuit is opened to the first timing relay. The three timing relays are slow-to-release and they release in sequence; a total delay time of some 700 milliseconds is provided before the last timing relay releases. If at this time the detection cycle has not been completed (which may be due to failure of the terminal equipment, failure of the terminal-digit marking relays to operate or to mark correct digits, or because the ticketing equipment has been accessed by a station not equipped for automatic number identification) the last of the timing relays will release, close the circuit to relay KG, and close ground to lead "Incomplete," to indicate to the Ticketer that the detection has not been satisfactorily completed. The Ticketer will then release the connection to the Detector, and the call will be routed to an operator.



"No Detect" Paystation Restriction Service

Provisions are made in the Detector for automatic identification of all stations which have access to the Ticketing equipment. This includes not only the stations which are to have automatic number identification, but also the stations which are not to have this service (the latter category may include paystations, subscribers' stations on multiparty lines which have no provisions in their telephones for station-number identification, etc.).

In the case of paystations, all incoming leads are wired through individual lamps and resistors, and then multipled to a common read-out relay circuit, which is similar to the MC relay circuits. The read-out relay, when operated, provides a "paystation restriction" mark to the outgoing trunk circuit, which releases the Detector and returns busy tone to the calling station.

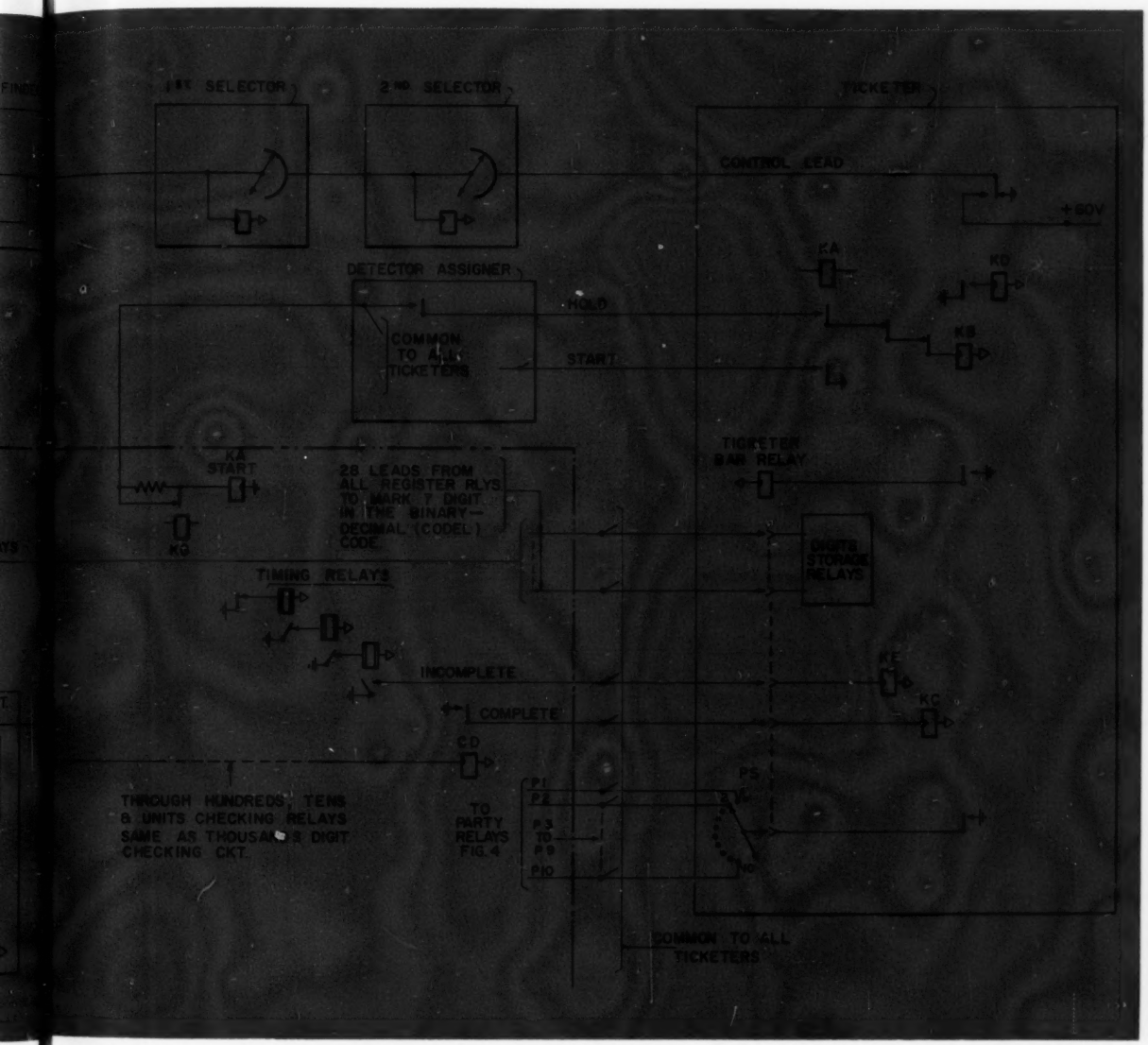


Figure 7. Overall Schematic for Equipment Involved in Detection

If some stations in a connector group are not to have automatic number identification, the leads incoming from these stations may be wired through their lamps and resistors like the others, but must be connected to the ND ("No Detect") bus. All ND buses are then multipled and connected to a "No Detect" relay circuit (similar to the MC relay circuit). When this relay operates, it provides a "No Detect" indication, which may either route the call to an operator or return busy tone to the calling subscriber.

Fault Conditions

If all stations in the office are equipped for automatic identification, failure to complete the detection cycle within the release time of the slow-to-release timing relays indicates a failure in the equipment; thus, when the last timing relay releases, the circuit is closed to the Fault relay. The Fault relay operates, locks to ground on the Reset key, closes the circuit to the Fault lamp, opens the "firing" circuit of all neon lamps, and closes the alarm-lead circuits. The neon lamps which were

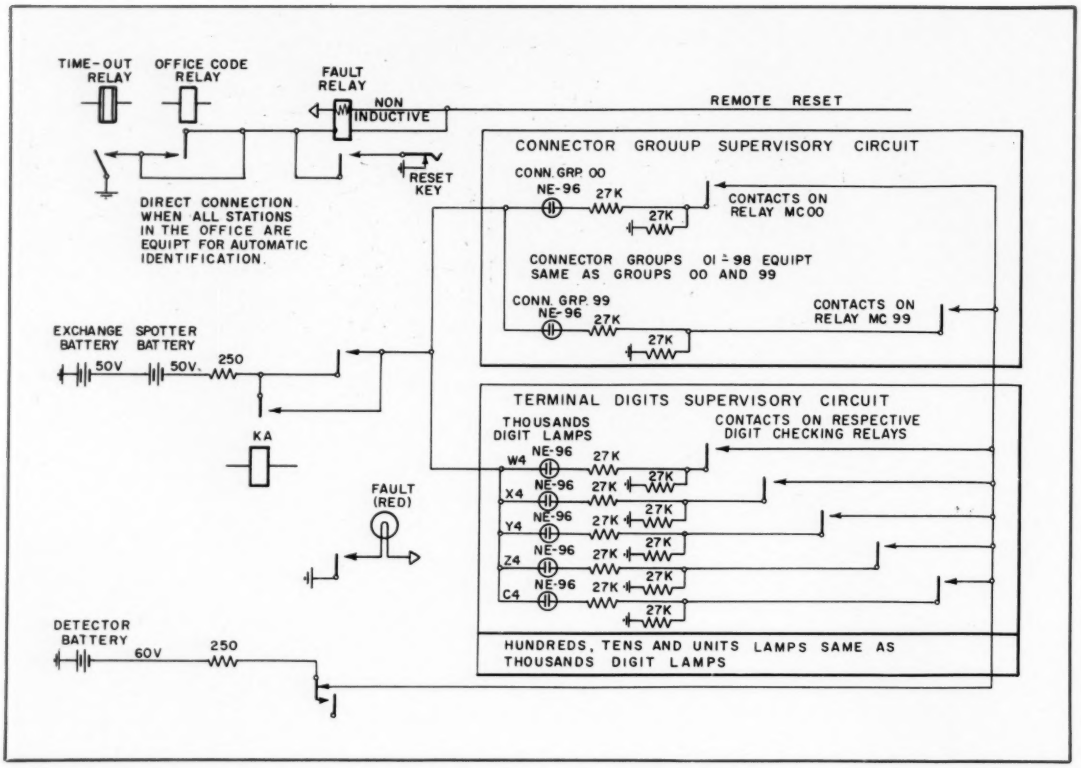


Figure 8. Connector Group and Terminal Digits Supervisory Circuits

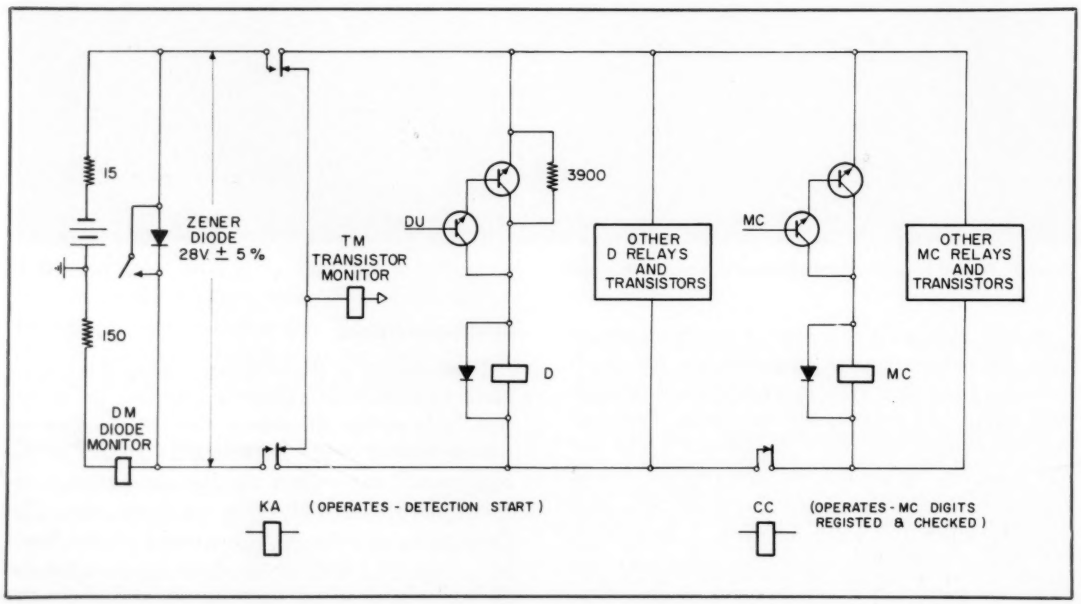


Figure 9. Zener Diode Regulated Voltage Supply for Transistor

lighted during this detection cycle will now remain connected in series with 100 v. battery, and since the sustaining voltage of these lamps is 75 v. ± 10%, they will remain lighted until the Reset key is operated. On succeeding detection cycles, absence of "firing" voltage will prevent the neon lamps from lighting.

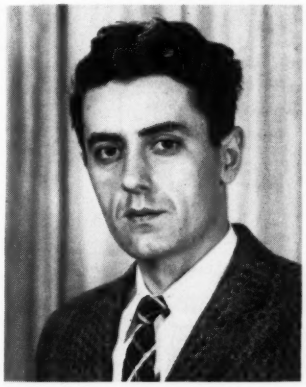
In offices where Ticketing equipment may be accessed by stations which are not equipped for automatic identification, the circuit to the Fault relay is extended through the make contact of the office-code relay. This assures that the alarm will not operate, and falsely indicate failure of the equipment, in case one of these stations accesses the ticketing equipment.

Summary

Detector equipment has been designed which will economically provide automatic detection for frequency-per-terminal offices. This equipment is suitable for smaller offices and may be readily expanded for use in larger offices. It has been miniaturized and employs up-to-date printed wiring techniques. All cross-connecting is quickly accomplished by means of patch cords which require no soldering. Parties are easily recognized and identified and changes may be made at any time with minimum disruption of service. Patch cords, or entire board assemblies, may be omitted as desired, yet quickly provided when the service is called for.

This Detector represents the utmost in simplicity of design and efficiency of operation.

RUDOLPH L. STOEHR graduated from Northwestern University in 1950, with a Bachelor of Science degree in Electrical Engineering. He began his work with Automatic Electric in Quality Control and later entered the Training School. He has held assignments in Exchange Engineering, Apparatus Engineering, and the Testing Bureau. Mr. Stoehr is now assigned to the Product Design Section of Laboratories as a Project Engineer, working on equipment and process developments.



BORIS SHERSTIUK came to Laboratories in 1956 after attending the University of Illinois, where he majored in Electrical Engineering. After two years in the Circuit Explanation Section he was transferred to the Toll Ticketing Section, where he is now engaged in circuit development work.

AUTOMATIC ROUTINERS *for* DIRECTOR-TYPE SATT SYSTEMS

By J. P. [redacted]

To make sure that Strowger Automatic Equipment will operate under all normal and many adverse conditions, and to disclose incipient faults before they affect service, the equipment is periodically tested in accordance with a pre-planned program of routine maintenance, known as "routining." This testing is usually done manually, but it became evident long ago that this was a type of work that lent itself to automation, and so *automatic routiners* were developed—the first of them about 1930. With the increasing complexity of telephone switching networks, automatic routining has

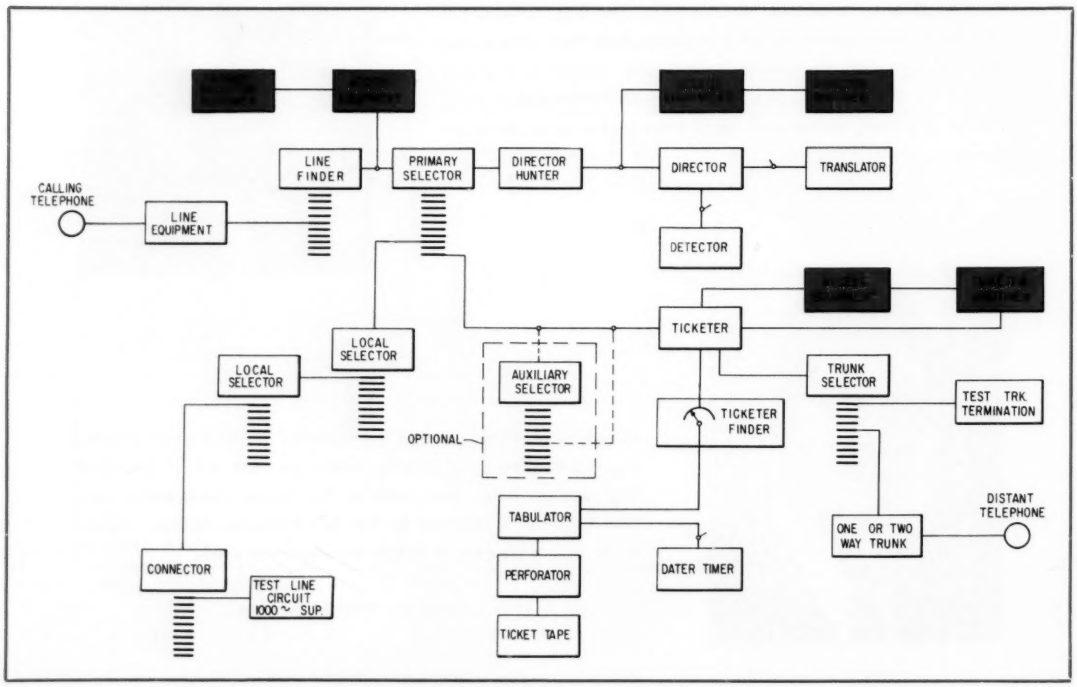


Figure 1. Connection of Automatic Routiners into Director Type SATT System

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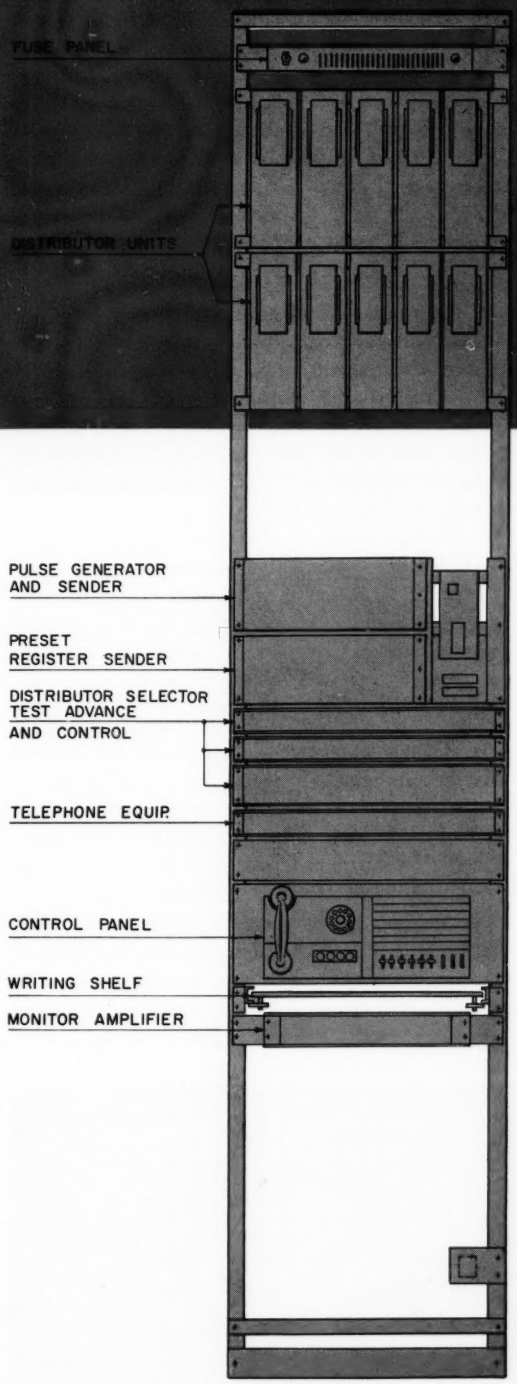

Figure 2. Primary Selector Routiner

been found by many telephone companies to solve two basic problems: the need to establish sound maintenance practices in large offices, and the high cost of adequate routining in such offices on a manual basis.

Most complex of all Strowger Automatic networks is the Type "A" (Director-type) SATT system used in large metropolitan areas. Laboratories has therefore developed automatic routiners, described herein, for Type "A" SATT equipment.

The Type "A" SATT system is fully automatic—requires only the dialing of a local directory number for a call within the home numbering-plan area, and only a toll area code, plus the local directory number, for calls to other areas. Detection and recording of the calling station number is automatic, even on party lines; party-line telephones are equipped with special dials having an auxiliary spring combination that identifies the calling station as the called number is dialed. Equipment and circuitry required to provide such completely automatic toll services are quite complex, and the great volume of traffic carried through these large systems necessitates prompt and efficient correction of any faults. Type "A" SATT equipment is regularly supplied with "monitor" panels that indicate the status of various equipment units as calls progress through them; these panels are so equipped that testing of individual units and of the overall system can be done from a central location. The automatic routiners described herein are an additional step toward assuring the establishment of sound maintenance practices in large SATT offices.

Automatic routiners required for Type "A" SATT equipment are: primary selector routiner, Director routiner, and ticketer routiner. These routiners will handle the three basic categories of SATT equipment in such an exchange, as shown in Figure 1.

Primary Selector Routiner (Figure 2)

The primary selector corresponds to the first selector in a non-Director system. Before subscriber dialing commences, the primary selector extends the call to a Director and indicates to it the class of service of the calling line. Its other functions (vertical and rotary stepping) are similar to regular selectors, except that it is always pulsed from a Director.

To adequately test such a selector, a routiner must be capable of making tests of every step in selector operation—seizure, class-marking, stepping to the correct level, switch-thru, etc. All these tests, and others, are provided by the new primary selector routiner, which can be made to access a maximum of 5000 primary selectors, and to routine them sequentially, one at a time, shelf by shelf. The routiner is placed in operation by simply operating a few keys on the routiner control panel (Figure 3).

To routine all primary selectors, in all shelves, the PRESET key is operated, followed by the START key. This causes the access equipment to select the first primary selector of the first shelf.

This selector is immediately tested to determine whether it is idle or busy. If it is busy, the routiner does one of three things; normally, it advances the access equipment to the next primary selector. However, if the routiner busy control key is placed in its TIMED CAMP-ON position, the routiner will "camp" on a busy selector for a specified time interval, before proceeding to the next one. Or, if the key is operated to the permanent CAMP-ON BUSY position, an audible signal will sound when the routiner finds a selector busy, and this signal will continue until the selector becomes idle, or the routiner is advanced manually, by key operation, to the next selector.

If the primary selector is idle, it will be seized by loop closure. At this point a test is made to determine if ground is being returned over the "C" lead by the "B" relay in the primary selector. If no ground is received, routining stops, a trouble-indicating lamp lights, and an alarm is sounded. If ground is returned over the "C" lead, the routiner permits the Director hunter to attempt to seize a Director and extend it to the primary selector. If no Directors are idle, "all-Directors busy tone" will be received; this fact is noted, and the routiner released. A second attempt is then made to routine the same primary selector. If neither dial tone nor busy tone is received, routining stops, a trouble-indicating lamp lights, and an alarm is sounded.

If dial tone is received, a continuity test is made of the leads which forward the "class" marking, via the primary selector, to the Director. If this test fails, routining will stop, and alarms are transmitted. If continuity exists over the "class" leads, the routiner sender is called into operation. A seven-digit local telephone number is pulsed out, directing the call to a test line termination that is connected to a one-milliwatt, 1000-cycle source.

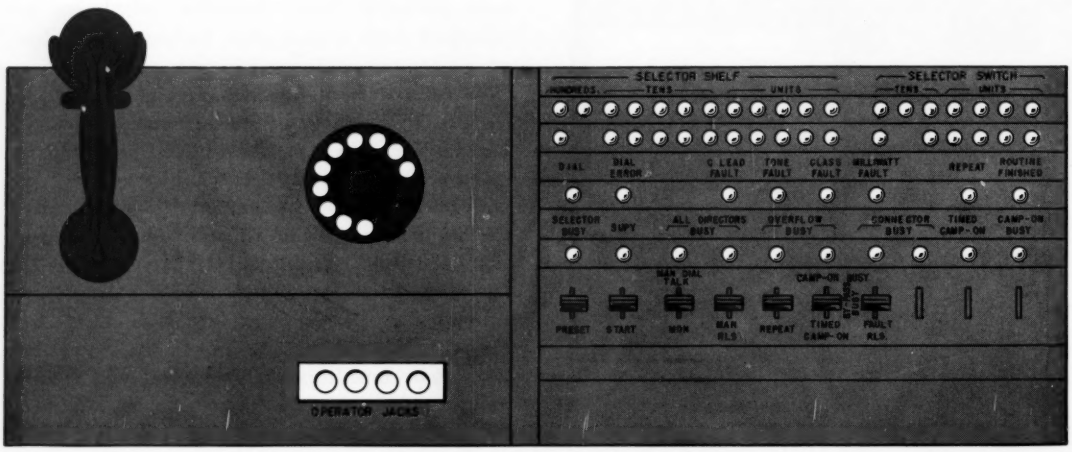

Figure 3. Control Panel for Automatic Primary Selector Routiner

After five digits have been sent, a test is made to see if an overflow busy tone has been encountered anywhere along the established switch train. If so, this fact is recorded, and the routiner releases; a second attempt is then made to routine the same primary selector. If no overflow busy tone is received, the last two digits of the local test number are sent out by the routiner, to seize the Test Line Termination circuit.

After seizing the Test Line Termination circuit, the routiner waits for the period of a complete ringing cycle, to insure tripping the ring-trip relay in the connector. After this timed interval, the routiner tests for the 1000-cycle tone. If the tone is received, the routiner releases, and the test of this switch is completed. The routiner then proceeds to access the next primary selector.

If line-busy tone is received, this fact is recorded, and the routiner releases. A second attempt is then made to routine the same primary selector. However, if ringback tone is received, or if no 1000-cycle tone is returned, routining will stop, and visible and audible alarms will begin.

Thus, in the manner described, all selectors are routined sequentially, and when the last primary selector of the last shelf has been tested, a signal is given, indicating that testing has been completed.

The routiner control panel has associated with it supervisory lamps which will advise the maintenance man as to the selector circuit being tested, and the point of failure of that circuit.

A "preset selection" circuit is also provided, which permits one to routine a specific primary selector, or to start the office routining operation with a specific selector. The PRESET key is operated, and an arbitrary three-digit code that has been assigned to that selector shelf is dialed by the maintenance man. Following this, a two-digit code is dialed to access the particular selector within the shelf. Now, when the START key is operated, the desired selector within the selected shelf is set up for test purposes.

If several test cycles are desired at one particular primary selector, the REPEAT key may be operated, and the same selector circuit will be routined continuously.

A manual test, talk, and monitor circuit is provided to facilitate manually testing a particular primary selector. When the routiner is set to "CAMP-ON-BUSY," the monitor circuit may be employed to ascertain whether selectors that test busy are actually in use.

Director Routiner (Figure 4)

The Director is a register-translator-sender applied to the Strowger system. When Directors are used, the subscriber is required, on toll calls within the home numbering-plan, to dial only the called station number—and on calls to other toll areas, only the toll area code plus the called-station directory number. The Director then automatically routes the call to the terminating office, and also, with the aid of the detector, accumulates and transmits to a ticketer the initial data required to produce a call record (ticket).

In order adequately to check the Director, an automatic Director routiner must, of course, be capable of initiating all types of calls that the Director is capable of handling (e.g., Local Calls of both the translated and non-translated type, AB Toll Calls, Long-Haul Toll Calls, 10-digit Free-Service Calls, Special-Service Calls, Reverting Calls, etc.). In addition, the routiner must be capable of checking on the supervisory features of the Director (e.g., fault seizure operation, incomplete detection, permanent signal timing, stop-dial operation, etc.). The new automatic Director routiner performs all the aforementioned functions—giving the operator 80 tests from which to choose by simple key operation.

This routiner can be made to access a maximum of 500 Directors, and to routine them in sequence, one at a time. All tests are "programmed" (i.e., one could test an entire office on one or on several items, or the entire sequence of tests could be applied to the entire office).

Associated with this routiner as an integral part is an automatic Digital Read-Out Printer which records the calendar date of the test, the particular test or tests being run (each test is identified by a number), the Director number, and whether the Director failed or passed a particular test or tests.

When it is desired to routine all Director circuits in the office, a PRESET key is operated on the Control Panel (Figure 5), followed by one or more TEST SELECTION keys (which determine the tests to be applied) and the START key. The automatic printer immediately records the date (month and day) and the numbers of the tests selected by the various operated TEST SELECTION keys.

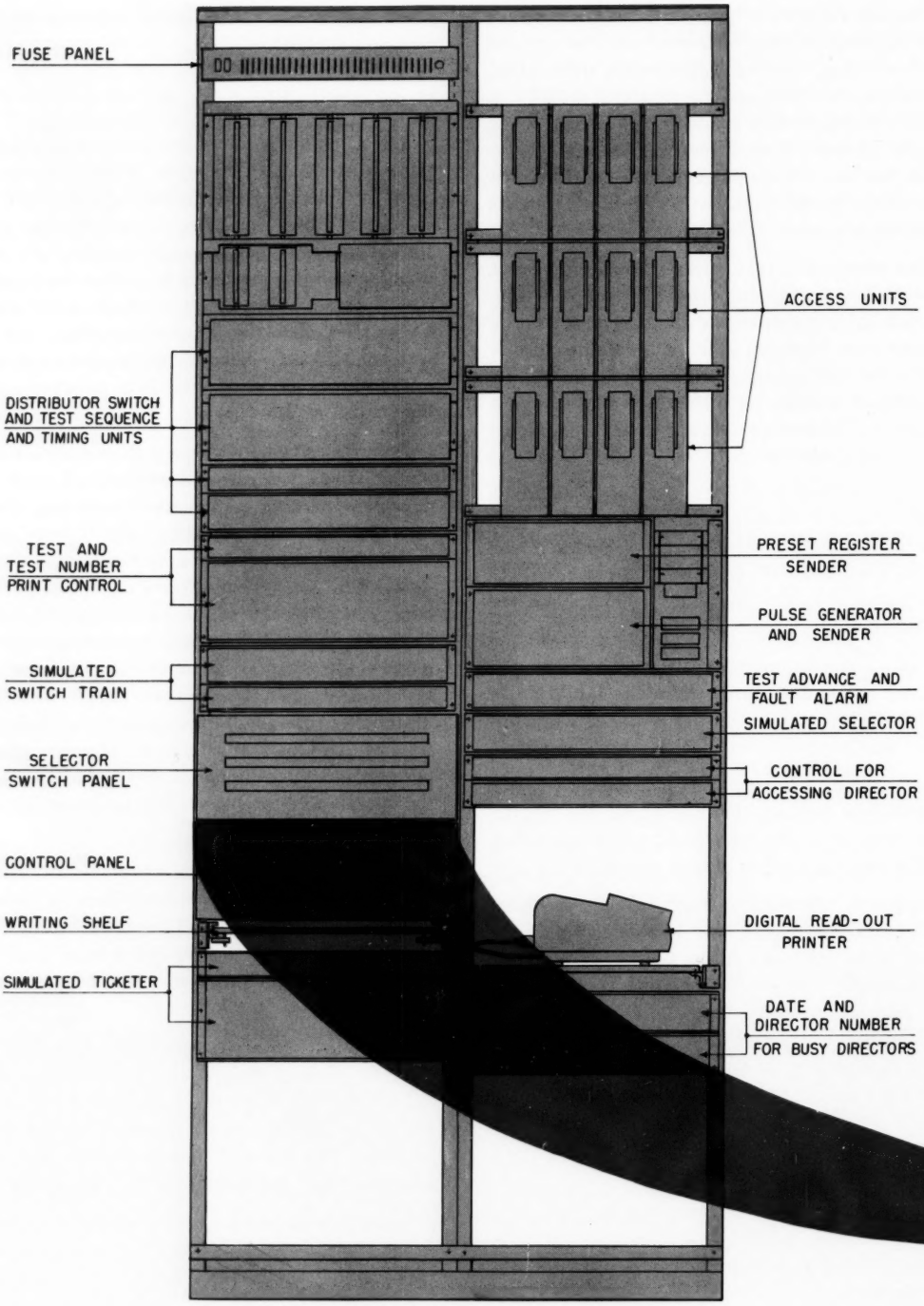

Figure 4. Director Routiner and Access Equipment

After this information is recorded, the access equipment steps off-normal, selecting the first Director in the office.

The "G," or guard, lead is now tested to ascertain whether the first Director is busy or idle. If it is busy, the routiner "camps" on this Director for approximately 60 seconds. If at the end of this time the Director has not become idle, a "marking" pulse is sent to the printer, and the access equipment is advanced to the next Director.

If the Director is idle (or becomes idle during the "camping" period), the routiner registers at the printer the number of the Director being routined. After this information has been sent, the routiner examines the leads between the Director and the Director Hunter, for crosses and foreign potentials. If the leads are satisfactory, the routiner closes resistance battery to the Director, to check its "pre-seizure" operation.

If the Director responds correctly, a tone-detection circuit is prepared to detect dial tone. When dial tone is returned by the Director, the routiner prepares to send the first selected test call into the Director.

It should be noted that if a Director fails the test for crosses and foreign potentials, or the "pre-seizure" operation test, or if it does not return dial tone, the routiner considers the Director as having failed the basic seizure test; the Director number and a code number denoting such a failure will then be recorded by the printer. An alarm will be sounded continuously (this alarm must be released manually); however, the routiner will not stop but will continue its testing on the next Director.

If a Director successfully passes the basic seizure test, the routiner proceeds to call its sender into operation, causing the first digit of the first test call to be sent into the Director. The remaining digits of the test call are subsequently sent and, depending upon the type of test call, the routiner's simulated ticketer and simulated switch train may be called into operation. The information received from the Director by each of these units is then compared with the correct information marked on the banks of the test sequencing switches. If the information received agrees with that marked on the banks of these switches, the routiner checks for proper release of the Director. If the Director releases correctly, the routiner considers it to have passed this first call test successfully, and proceeds to apply the second test call to the same Director.

Assume that the Director fails on the second test call. The number of the test, plus a number that indicates which portion of the test the Director failed, will be recorded by the printer, and, as above, a continuous alarm will be sounded, while the routiner continues its testing operation on the next Director.

A "STOP ON FAULT" key has been provided in the routiner, so that, if desired, it will stop routining when a fault is encountered; use of this key is left to the discretion of the operator. By operating keys on the routiner control panel, loop and leak conditions may be applied to the Directors, to simulate line conditions. The routiner also has facilities to test the Director's ability to receive and record SATT "spotter" dial pulses.

After testing the last Director in the office, a signal is given, to indicate that routining has been completed.

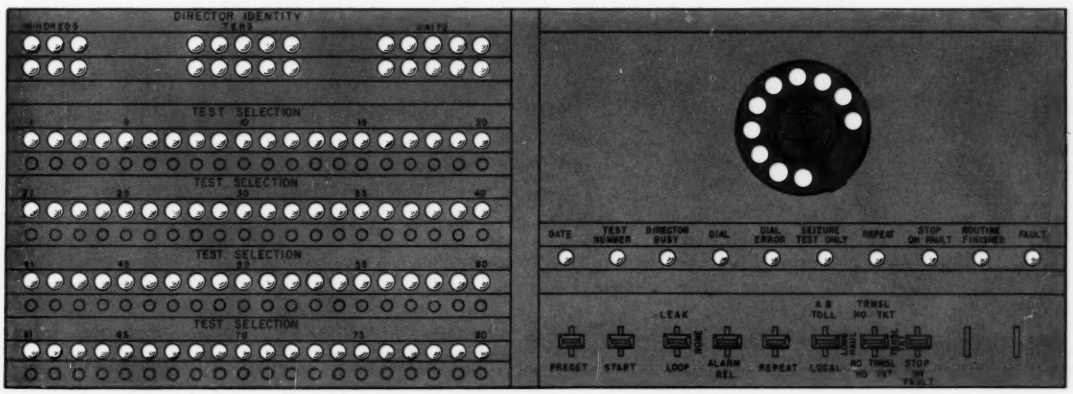

Figure 5. Control Panel for Automatic Director Routiner

The routiner has associated with it supervisory lamps which indicate to the maintenance man the specific Director being tested, and the progress of routining.

As in the primary selector routiner, a "preset selection" circuit is provided which can be used when it is desired to routine a specific Director or to start office routining with a specified Director. The PRESET key is operated, as previously described, and the Director number is manually dialed. With the operation of the START key, the selected Director is set up for test purposes. If several test cycles are required on one particular director, the REPEAT key may be operated; the same Director will then be routined continuously.

In addition to all these completely automatic tests, the Director routiner is provided with a group of manual selector switches for additional special operating conditions, for which tests are not provided in the automatic portion of the routiner.

Ticketer Routiner (Figure 6)

The ticketer is the principal unit of the ticketing equipment. It stores all ticketing data that has been forwarded by the Director, remains with the call during the conversation period to time the call, adds the conversation time and the identifying number of the ticketer to the ticket data, and forwards this information to an idle tabulator for further processing. The new automatic ticketer routiner tests both short- and long-haul (7- and 10-digit) ticketers progressively and on a fully automatic basis.

The tests applied by the routiner to each ticketer are tests that years of experience have found to be desirable. Among these are tests of the ticketer's conversation-timing features, its storage data-sending ability, and the continuity of ticketer output leads, and an overall test that includes the relays in the trunk selector.

As with the Director routiner, the ticketer routiner has associated with it a "Digital Read-Out" printer which records the calendar date, the particular test or tests being run, the ticketer number, and whether the ticketer failed or passed a particular test or tests. A tape, equivalent to that produced by the Director routiner, is made by the ticketer routiner.

This routiner can be made to access a maximum of 500 ticketers. All tests are programmed and the routiner is placed in operation in a manner similar to the Director routiner.

When the access equipment is stepped off-normal by operation of the routiner START key, it checks whether the first ticketer is busy or idle, and whether this ticketer is a short-haul (7-digit) or long-haul (10-digit) ticketer.

As with the primary selector routiner described above, the ticketer routiner may do any one of three things, on finding that a ticketer is busy. Normally, it advances the access equipment to the next ticketer. However, if the TIMED CAMP-ON feature is used, the routiner will "camp" on a busy ticketer for a timed interval, before proceeding to the next one; or if the PERMANENT CAMP-ON BUSY feature is used, an alarm will sound until the ticketer becomes idle or the routiner is advanced manually (by key operation) to the next ticketer.

If the ticketer is (or becomes) idle, the routiner registers at the printer the number of the ticketer being routined. After this information has been sent to the printer, the routiner's simulated call recorder is placed in operation, seizing the ticketer via its test common leads. The routiner then proceeds to send simulated call data into the ticketer to actuate its codel data-storage equipment. In conjunction with this operation, the trunk selector is seized and stepped to a level having access to a "test termination" trunk.

After all pulsing has been completed, the trunk selector, and subsequently, the test termination trunk, are checked for switch-thru operation. If these conditions are correct, the ticketer is placed in the "answer" condition. A predetermined number of time pulses are now sent to the ticketer conversation-timing circuit. These pulses are like those used in the timing of calls, but are sent at a high speed. After the pulses have ended, the routiner will initiate the release of the ticketer, as if upon completion of a regular ticketed call.

The routiner now initiates a continuity check of the leads between the ticketer and its simulated tabulator; if the ticketer passes this test, it is allowed to transmit its stored ticket data. The information received from the ticketer is then compared with the correct information, marked on the banks of the routiner's test-sequencing switches. If the information received agrees with that marked on these banks, the routiner considers the ticketer as having passed this test successfully, and proceeds to

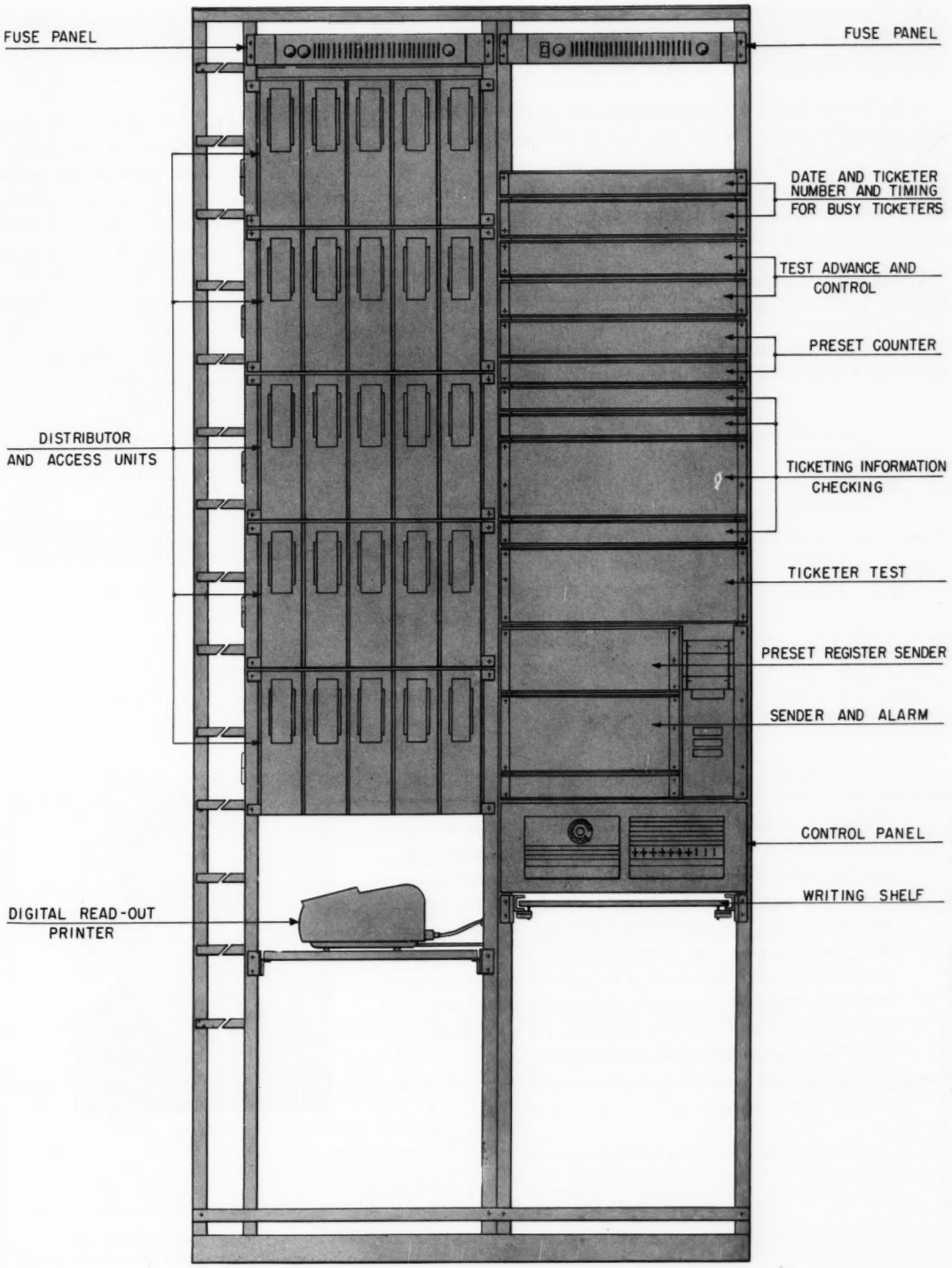

Figure 6. Ticketer Routiner and Access Equipment

apply a second test call to the same ticketer. A series of only four tests of this kind is required to assure the proper functioning of all codel units.

If the ticketer fails the second test call, the printer will record the number of the test, and of that portion of the test that failed. An audible alarm will also be given, which must be released manually; however, the routiner will not stop but will continue its testing operation on the next ticketer.

When the last ticketer has been tested, a signal is given, indicating the conclusion of routining.

As with the Director routiner, the ticketer routiner has a REPEAT TEST feature and a preset selection circuit, each of which operate as previously described.

Summary

The three routiners described, used together as a complete automatic routiner for Type "A" SATT equipment, put all the basic equipment units "through their paces" in such a way that the operating company may be sure of satisfactory operation. These routiners test all details of switch operation—accurately, and rapidly.

In the latter part of this year the first SATT routiners of this type will be placed in operation by Middle States Telephone Company of Illinois in its Park Ridge and Des Plaines Offices.

JOSEPH P. JALLITS graduated from Illinois Institute of Technology in 1950, with the degree of B.S. in Electrical Engineering. He joined Automatic Electric that same year as a student in the training school. Following completion of the course, he was assigned to Installation, Exchange Engineering, and the Testing Bureau. He is now assigned to the Telephone Switching Systems Department of the Laboratories as a project engineer, where he is presently doing development work on test equipment and automatic routiners. He is a member of the American Institute of Electrical Engineers.

CONTINENT-WIDE DIALING IN CANADA

Progress has swept away two stalwarts of the telephone industry in British Columbia — the old Victoria and Vancouver long-distance switchboards. The FW-1 Intertoll Switching System, with

its associated FW-1 Cordless Switchboards, has stilled the old toll boards that were direct decendants of the primitive devices that made possible the first long-distance telephone line in the province.

British Columbia is served By British Columbia Telephone Company and its associate, the Northwest Telephone Company. The first installation of FW-1 (four-wire) equipment was made in the B. C. company's New Westminster exchange, which was completely described in the December, 1956, and June, 1957, issues of the General Telephone Technical Journal. The new FW-1 exchanges are much larger—having approximately 200 positions. With this cutover, this area becomes part of the Continent-wide Operator Dialing Plan, enabling operators to complete calls on a dial basis to most points in Canada and the U.S.A.

The entire FW-1 system was developed in the Laboratories, with the close co-operation of the British Columbia Telephone Company, and was produced by Automatic Electric. It consists entirely of step-by-step equipment; its features (many used here for the first time) include: four-wire switching of transmission paths throughout; split-pad switching, with increased gain on high-loss connecting trunks; automatic, alternate routing and code conversion; camping of calls on busy trunks; centralized traffic supervision and automatic recording, and high-speed, automatic, cordless toll boards.

NEW NEGATIVE-IMPEDANCE REPEATER UNDERGOING TESTS

Laboratories is at present field-testing a newly developed negative-impedance voice-frequency telephone repeater, to be known as the AT-5. Designed for use on H-88 loaded cable in the majority of gauges used currently, this combination series-shunt repeater (contained in a housing 2″ x 5¼″ x 9½″) is undergoing tests in Michigan, California, and West Virginia. Its design practically eliminates the involved strapping of the previous type of repeaters, and provides a switch for the adjustment of gain.

After tests have been completed, and test results analyzed, the Technical Journal will carry a complete description of this new development.

TALKS AND PAPERS BY LABORATORIES PERSONNEL

"Low Temperature Impurity Conduction in Silicon" by Dr. Thomas A. Longo, January, 1959, issue of Journal of Physics and Chemistry of Solids.

"Introduction to Electronic Telephone Switching Systems and Memory Requirements and Techniques" by D. K. Melvin, presented as a speech before Etta Kappa Nu, Honorary Fraternity of Electrical Engineers, University of Wisconsin.

"Digital Encoding Techniques in Communications Systems" by K. C. Keyda; presented as a speech before Etta Kappa Nu, Honorary Fraternity of Electrical Engineers, University of Wisconsin.

"Lossless Transmission Circuit for An Electronic Telephone Switching System" by L. K. Lugten; presented as an AIEE paper before the Summer and Pacific General Meeting, Seattle, Wash., June 24, 1959.

"Transistorized Universal Tone Detector" by E. J. Glenner; presented as an AIEE paper before the Summer and Pacific General Meeting, Seattle, Wash., June 24, 1959.

"Transistorized Negative-Impedance Telephone Repeater" by R. P. Dimmer; presented as an AIEE paper before the Summer and Pacific General Meeting, Seattle, Wash., June 24, 1959.

This paper was presented by Mr. Glenner at the AIEE Summer and Pacific General Meeting, Seattle, Wash., on June 24, 1959. It appears in the Technical Journal by permission of the American Institute of Electrical Engineers.

TRANSISTORIZED UNIVERSAL TON

By E. J. Glenner

Introduction

In the field of telephony, tones are frequently used for transmission of information. Dial tone, busy tone, and ring-back tone are all familiar supervisory signals intended for use by a telephone subscriber; with a minimum of experience, their meaning may be understood. Additionally, a variety of other tones are employed exclusively for use by a telephone operator. For example, a "zip-zip" tone alerts an operator to the fact that she is being connected to a telephone subscriber; "paystation" tone following the zip-zip tone warns that the subscriber is calling from a paystation and coins must be deposited.

Besides the many applications requiring aural recognition of tones by a telephone subscriber or operator, tones are frequently used for signaling purposes wherein equipment automatically detects its presence; if tone is present, the call may be routed to one specific type of service; absence of tone results in a different routing. A new Transistorized Universal Tone Detector has been developed by the General Telephone Laboratories to automatically detect such tones. This device is capable of detecting tone frequencies within the entire normal telephone speech spectrum rather than being limited to one specific frequency. Further, the tone detector input impedance can be varied so that this device may be employed for a wide range of applications and is, therefore, considered universal in nature.

Tone Detector Requirements

The original design requirements of this tone detector were set by a specific application: that it be a low impedance device which would reliably detect a valid tone (alternating potential) and give a positive indication of this fact. For low input-impedance applications, the tone detector must fulfill the following requirements:

1. It must detect tones falling within normally accepted telephone speech frequency range of 300 to 3500 cycles per second at approximately 1.0 volts rms.
2. It must offer negligible additional impedance when in series with a (500 ohm) "stopping battery."
3. The input circuit should be able to pass direct currents of up to 200 milliamperes without saturating.
4. The input circuit must be filtered to prevent false operation due to noise or high-frequency voltage surges or transients.
5. The detector relay requires a minimum rectified operating direct current of 13 milliamperes; for reliable release, the direct current must be less than 5 milliamperes.
6. Relay operating time should be nominally 75 milliseconds, to guard against false operation.

Other requirements were set in the interest of good engineering: circuit components must be pro-

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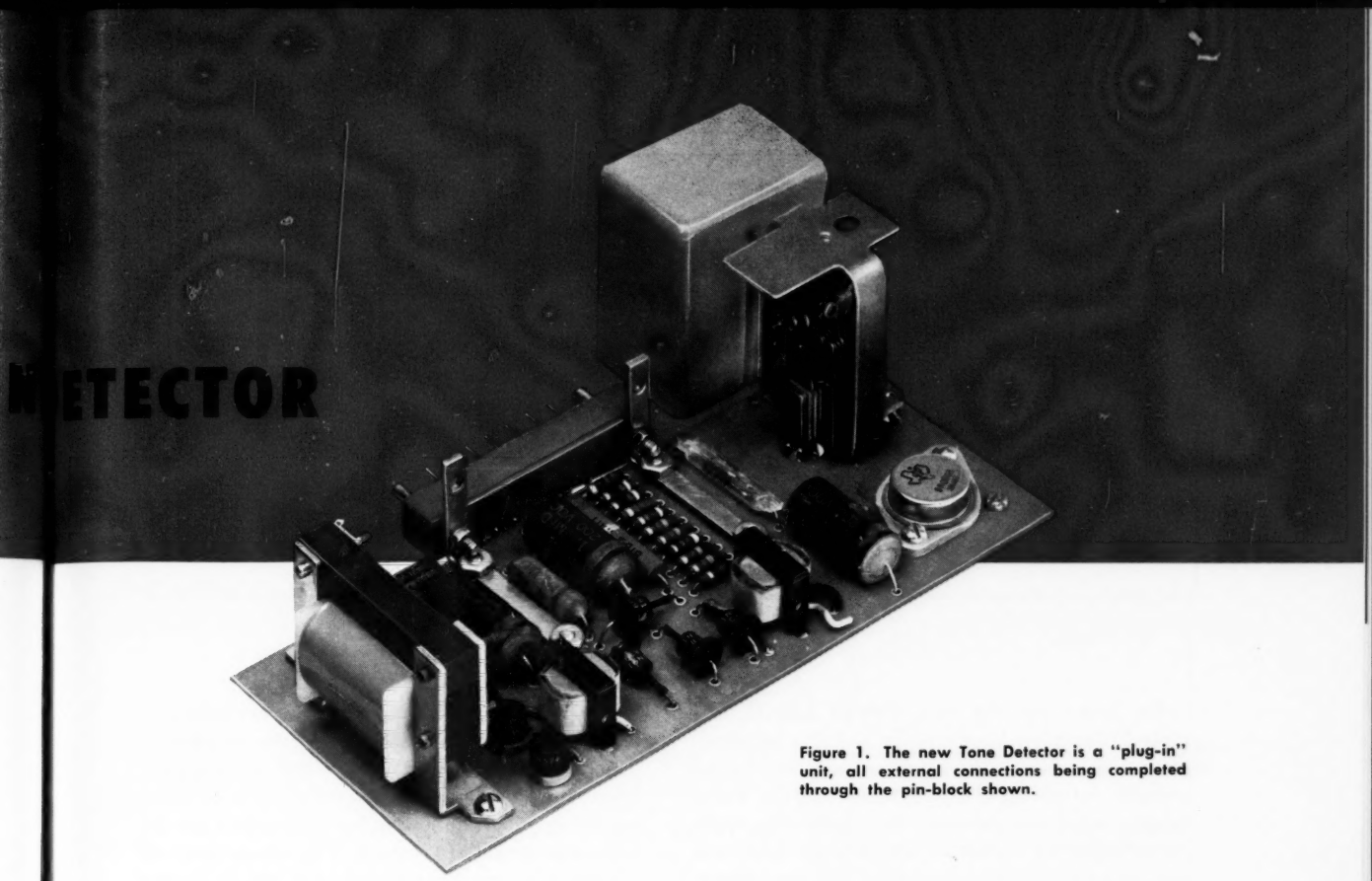


Figure 1. The new Tone Detector is a "plug-in" unit, all external connections being completed through the pin-block shown.

tected from damage due to momentary overloads or voltage transients, the tone detector must be independent of ambient temperature variations up to +55°C (+131°F), and the unit must be small.

In addition to the original requirement of a low-impedance input, it is desirable, for future applications, that the tone detector be adaptable for use as a high-impedance device or have a specific value of input impedance—say, 600 ohms or 900 ohms. The resulting device is thus universally acceptable for use with circuits requiring matching to a variety of detector input impedances. Changes of input impedance are to be accomplished by providing optional input equipment.

The Transistorized Universal Tone Detector is shown in Figure 1. This unit, designed for 48-volt direct-current operation, is completely self-contained, including the small Class "E" detector relay, which is mounted as an integral part of the circuit. Components have been miniaturized; small radio-type resistors, capacitors and transformers are used where possible. The input transformer (at the left of Figure 1) was chosen with a sufficiently large core to prevent saturation when it is required to pass direct currents. Being small and self-contained, the detector was designed to mount as a plug-in unit.

Applications

One specific use for the new Tone Detector is illustrated in Figure 2. With the advent of Direct Distance Dialing, subscribers are permitted to dial certain toll calls themselves from regular stations, while calls originating from paystations require special handling. When a call originates from a regular subscriber, (S1), with no tone impressed on the "control (C) lead" at the line equipment, the call is automatically channeled to Direct Distance Dialing facilities. When a call originates from a paystation, (S2), a "class-of-service tone" is impressed upon the "control (C) lead" at the line relay equipment. During trunk selection, the "C" lead is momentarily extended to the tone detector equipment. Upon detection of tone, the call is automatically routed to a recorder announcer or an intercept operator for special handling.

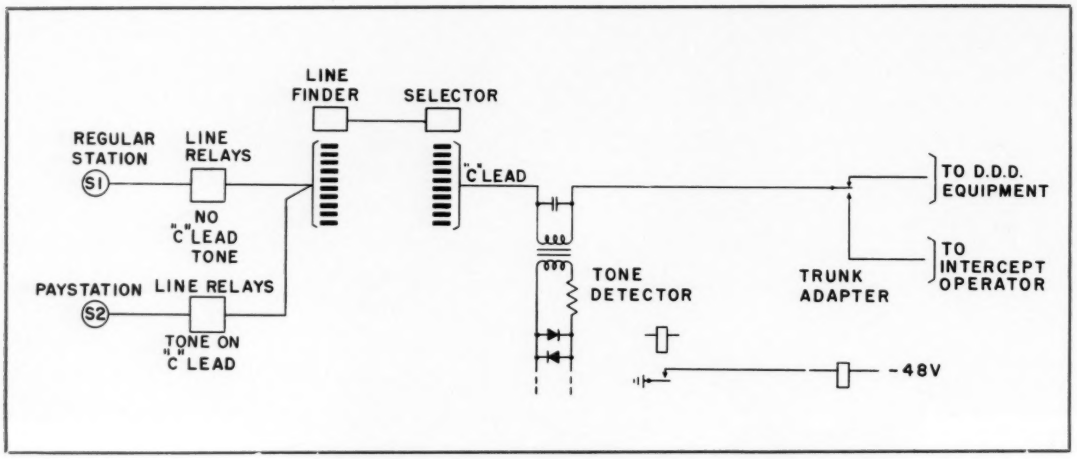


Figure 2. Paystation Discrimination by Tone Detector

For future use, the tone detector may be employed to monitor tone supplies and give an alarm in case of failure. This equipment may also be acceptable for use in detecting tones used for transmission measuring purposes. Practically any application requiring a sensitive tone-detector with variable input impedance may utilize this new design.

Circuit Details

Input Circuit

The circuit schematic of the Transistorized Universal Tone Detector is shown in Figure 3. With its input consisting of an eight-ohm transformer primary winding bridged by a 0.25 microfarad capacitor, the resultant filter functions as a high-frequency (noise and transient) by-pass. Figures 4 (A) through (D) show input circuit variations that may be obtained with the Transistorized Universal Tone Detector.

One typical circuit of a telephone switching system control (C) lead is shown in Figure 4(A) with a ground circuit at the trunk adapter. The "C" lead must be maintained close to ground potential at all times, to keep the switch-through relays operated and also to prevent intrusion from other circuits. Input impedance of the tone detector for this use is essentially eight ohms, since the secondary winding of the input transformer is bridged by a low-impedance diode limiter which reflects a low impedance to the primary winding. For this application, with switch-through relays of 1300 ohms resistance as a typical value, it is seen that the primary winding of the input transformer must pass a direct current of 100 milliamperes or greater. During the time allotted for detection, an "absence-of-ground" searching selector switch will not stop on this guarded connection but will, rather, use the eight-ohm ground to step-off. This sets up large oscillations in the input transformer which last for approximately 18 milliseconds; hence, the requirement mentioned previously that the detector relay operation be somewhat delayed to guard against false detection.

Figure 4(B) shows the tone detector as a series device. With this "battery-searching" arrangement, the series eight-ohm transformer primary winding offers negligible additional impedance when in series with the stopping battery.

In Figure 4(C), the tone detector is used as a high-impedance device. Here, the input transformer has been replaced by a small series-capacitor arrangement which offers a relatively high input impedance at audio frequencies. In Figure 4(D), larger capacitors are used, and a series resistive element is introduced to offer a specific input impedance (600 ohms, in this example).

Limiting and Amplification

In addition to reflecting a low impedance into the input circuit, a diode limiter (Figure 3) protects the tone detector from high-voltage input surges. Two 1N91 diffused-junction germanium diodes, CR1 and CR2, provide limiting action at approximately 0.5 volt input; limiting is essentially

flat even with high-voltage input surges. With a current-limiting resistor of 15 ohms resistance, the diode limiter is protected from extreme surges.

Two stages of amplification are employed with 2N524 germanium PNP alloy-junction transistors powered from a low-voltage divider circuit of approximately 10 volts. These transformer-coupled amplifier stages (operating class "A") are "self-biased" so that gain is almost completely independent of ambient temperatures up to +55°C (+131°F).

Alternating-current output from the second stage of amplification is full-wave rectified, using a center-tapped transformer and germanium diodes CR3 and CR4. For the final stage, a PNP type 2N457 germanium power transistor is "back-biased" to minimize leakage. Typical approximate values of leakage current (collector or relay current) are 0.5 milliamperes at +25°C (+77°F), rising to 2.0 milliamperes at +55°C (+131°F). Since the detector relay in the collector circuit of the final stage is margined to operate on a direct current of more than 13 milliamperes, and releases at approximately 9 milliamperes, leakage current has no harmful effects on circuit operation. Under normal operating conditions, the relay direct current is 25 to 30 milliamperes.

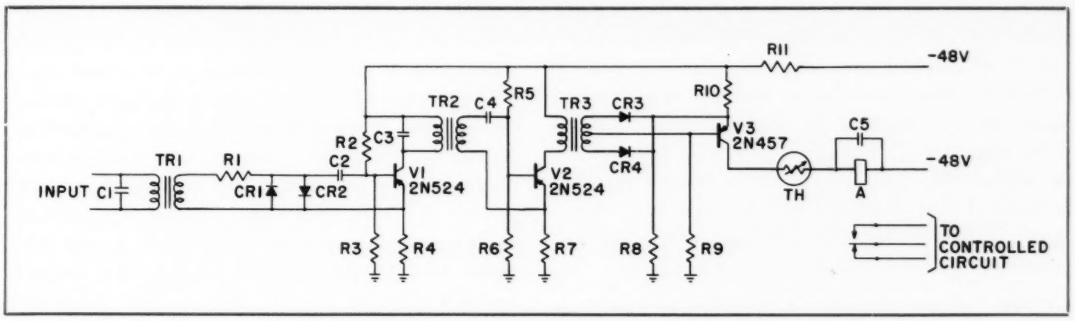


Figure 3. Tone Detector with Low Impedance Input

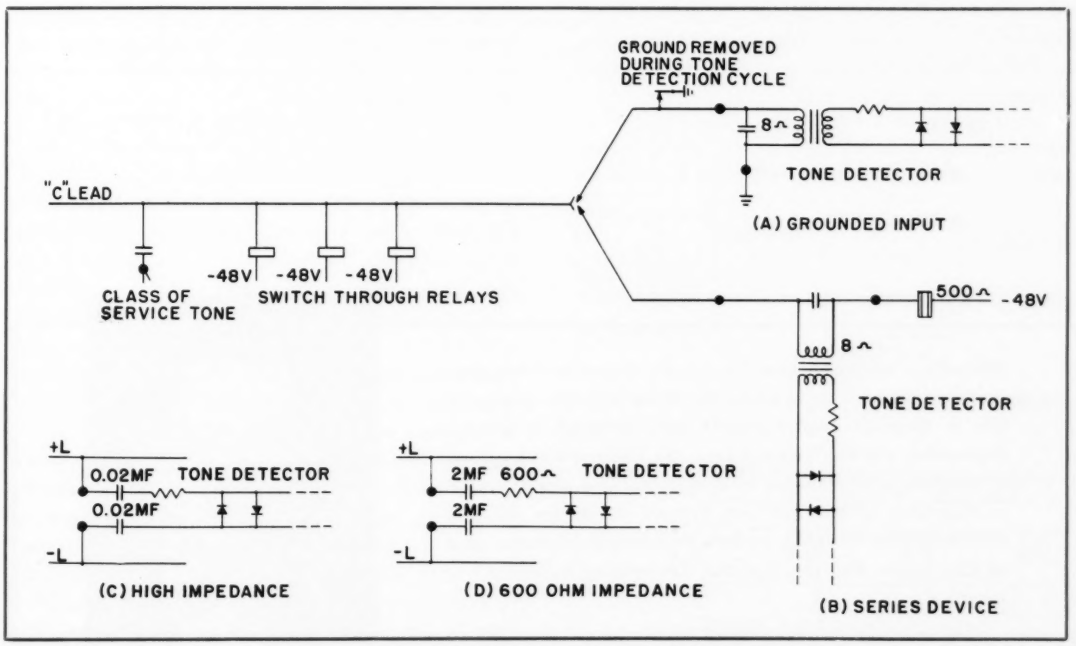


Figure 4. Tone Detector Showing Input Variations

The power transistor is protected from detector-relay inductive kicks by a relay-bridging capacitor which also smooths rectified ripple current. For many similar applications, relays operating in transistor collector circuits are bridged with diodes to protect the associated transistors. However, since the detector relay used here has a very small magnetic structure, inductive surges are effectively suppressed by means of a 1.0 microfarad bridging capacitor.

In many applications, the tone detector may be subjected to noise or spurious transients at its input. Although at least 75 percent of this unwanted noise is by-passed at the input transformer, some amount may be amplified and passed on to the detector relay circuit. To guard against such false signals, a thermistor is provided to introduce a nominal 75 millisecond operating delay for the relay. With a low-impedance input the tone detector is capable of detecting tones having a minimum value of 0.1 volts rms of frequencies as low as 200 cycles per second. On occasion, a 135-cycles-per-second mechanical tone-generator may be used as a tone supply; usually the signal is sufficiently rich in upper harmonics so that it may be detected with ease.

When the tone detector is operated as a high-impedance device and the input transformer replaced by coupling capacitors, tones with a minimum value of 0.25 volts rms may be detected; see Figure 4(C). At nominally high impedance inputs, say 600 ohms or 900 ohms, greater sensitivity may be expected; see Figure 4(D).

Miscellaneous Considerations

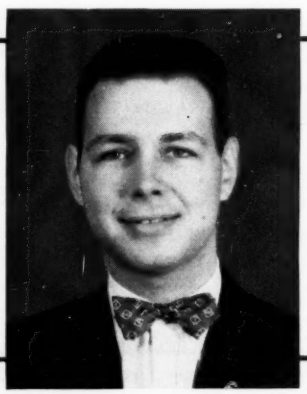
While the detector was in the development stage, careful consideration was given to physical arrangements to reduce crosstalk interference; by careful mounting of components, leads were kept short, reducing stray capacitive effects. With the input transformer apart from, and at right angles to, the detector relay, induction from small amounts of leakage current in the relay (0.5 milliamperes, for example) has virtually no effect upon the input circuit. To further insure reliable operation, a relay cover is provided for magnetic shielding.

Field Trials

One prototype of the Transistorized Universal Tone Detector was placed in service in the Laboratories' private automatic exchange, as a field trial. This detector was connected to unassigned selector levels so that it would be accessed by any subscriber dialing an unassigned number. One specific telephone line was provided with tone impressed on its control (C) lead. When the detector was accessed by this station, a successful detection would take place; no detection from any other station. Seizure and detection peg counts taken of 2000 calls indicate no erroneous operations.

An additional test of the tone detector was made at the Ortonville office of the General Telephone Company of Michigan. Here, the tone detector was successfully used in a paystation trunk restrictor operation, as in Figure 2.

EDWARD J. GLENNER joined Automatic Electric in 1948 after graduating from Northwestern University with the degree of B.S. in Electrical Engineering. He was assigned to Systems Engineering and the Testing Bureau. Mr. Glenner was engaged in toll systems development until 1958, when he was promoted to Supervisor of the Switching Systems Laboratory. He is a member of the American Institute of Electrical Engineers, and of Eta Kappa Nu, the Electrical Engineering honorary fraternity.



Mr. Lugten presented this paper at the AIEE Summer and Pacific General Meeting, Seattle, Wash., on June 24, 1959. It is reprinted in the Technical Journal by permission of the American Institute of Electrical Engineers.

Lossless Transmission Circuit for an Electronic Switching System

By L. K. Lugten

In the April, 1959, issue of the Technical Journal we presented an article on a small experimental Electronic Automatic Telephone Exchange using Time-Division-Multiplex techniques. The circuit in this exchange employed storage capacitors in each terminal to increase the transmission efficiency, as is commonly done in multiplex systems. However, in such a circuit the transmission efficiency will decrease greatly when low repetition rates are used to accommodate more time channels, while retaining a fixed width of time slot for each channel. This loss is due to the fact that the average value of charge on the storage capacitors will drop far below the peak value, which is equal to the signal which would be transmitted if there were no losses.

The following article describes a circuit which overcomes this limitation by anticipating the loss in charge of the storage capacitors and produces a proportionately greater peak value, such that the average charge is made equal to the signal, which is therefore transmitted without loss.

This circuitry provides a lossless connection between subscribers of a Private Automatic Branch Exchange (P-A-B-X) without using the conventional hybrids and amplifiers. The highway is bidirectional, and amplification in either direction has been obtained by using an auxiliary signal which controls the overall gain. The system can handle 40 sources of information simultaneously. The switchboard has been equipped with 14 links and 12 trunk circuits. The system logic and design considerations will not be described in this paper except for a short description of the timing and pulse generation necessary for this discussion. This electronic P-A-B-X employs 40 time-slots of 2 microseconds each, hence the repetition rate is 80 microseconds. Each time-slot consists of a 1.5 microsecond multiplex pulse for opening the gates, and a 0.5 microsecond guard pulse. These pulses will be referred to as the multiplex pulse 1.5 (cp-1.5), and the guard pulse 0.5 (cp-0.5).

The circuit arrangement for obtaining these required pulses is shown in Figure 1. The sine wave oscillator is crystal-controlled for frequency stability. The pulses appearing at the output terminals are shown in Figure 2.

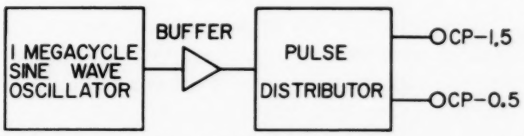


Figure 1. High Speed Clock

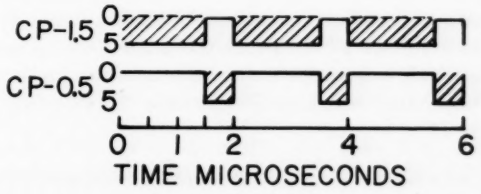


Figure 2. Output Pulses

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Transmission Circuit

A simplified circuit (Figure 3) explains how a one-way connection from the sending generator Vg to the receiving load (represented by the resistor R_6) can be established. Since the return connection is very similar, this explanation should be adequate. On the sending side of the highway a line gate is shown, and on the receiving side a link gate. The highway consists of two transformers; their functions will be explained later. Transistors Q_1 and Q_2, usually in cut-off condition, will be turned on when coinciding multiplex pulses appear at the inputs of "and" gates I and II. By clamping the bases to a constant voltage with diodes CR_4 and CR_8, capacitors C_1 and C_2 will be charged with a constant current in opposite directions. Hence, the potential at C_1, which is initially on —15V, tends to go to ground, and the potential at C_2, initially at —5V, will go to —20V.

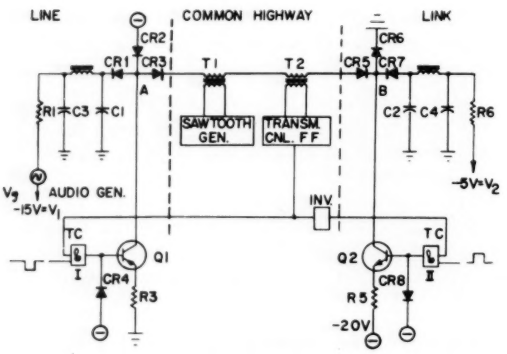

Figure 3. Transmission Circuit

It is apparent that at a certain moment (i.e., after ¾ microsecond) the voltage $Vc_1 = Vc_2$ (Figure 4A) and the highway will become conductive. There is a short time delay due to the small voltage-drop across CR_3 and CR_5; however, since this loss is so small it has been ignored in the following explanation.

As soon as the highway is conducting, a current tends to flow between points A and B (Figure 3), and a voltage will be developed across transformer T_2 which will set the transmission control flip-flop. This change of state will close the "and" gates I and II.

To simplify the explanation, the audio information which appears across capacitor C_1 is assumed

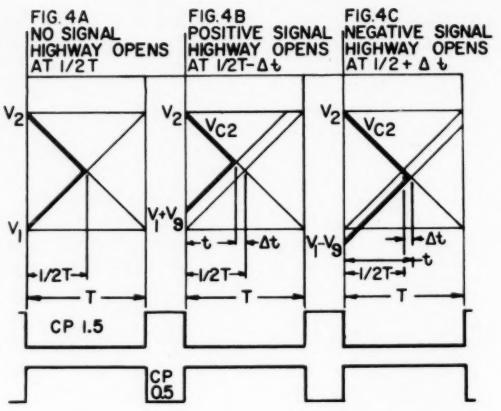

Figure 4. $\Delta_t E$ as Function of Audio Signal

to be of constant amplitude during the sampling time. (This has been demonstrated in Figure 5 with a sinusoidal signal of 3125 cycles per second, or one period of this signal is $1/F = 320$ micro-

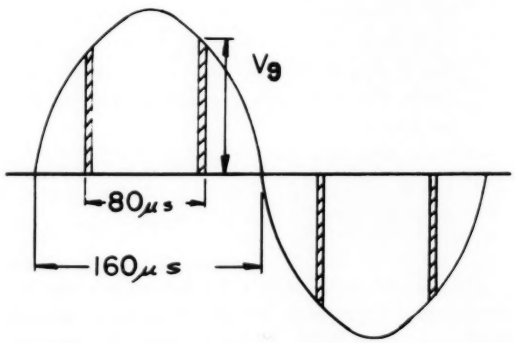

Figure 5. Sampling of Audio Signal

seconds. It is apparent that the sampling time is so short that this assumption is justified.)

The voltage over C_1 (Figure 3) due to the opening of the line gate is given by $Vc_1 = \frac{1}{C}\int idt$. Since the collector current i is kept constant, $Vc_1 = \alpha t$, in which $\frac{i}{c} = \alpha$. The behavior of the transmission circuit without modulation will be discussed first. This case has been represented in Figure 4A.

In this case the bias voltages V_1 and V_2 have been adjusted such that the highway opens exactly at the middle of the multiplex pulse.

For this condition the following relationship must be true:

$$V_1 + Vc_1 = V_2\text{-}Vc_2$$
$$V_1 + \alpha t = V_2\text{-}\alpha t$$
$$2\alpha t = V_2\text{-}V_1$$

By setting $t = \frac{1}{2}T$ we get

$$\alpha T = V \quad . \quad . \quad . \quad . \quad (1)$$

in which $V_2\text{-}V_1 = V$

V and T will be predetermined; hence equation (1) gives an expression for the required collector current of the line gate and link gate transistors.

When an audio signal appears across capacitor C_1, and making use of the assumption that the audio is constant during the sampling period, the highway will open when a new condition has been met:

$$V_1 + \alpha t + Vg = V_2\text{-}\alpha t$$
$$2\alpha t = V\text{-}Vg$$
$$\alpha t = \frac{V\text{-}Vg}{2}$$

$$\text{Using } \alpha = \frac{V}{T}$$

$$\text{gives: } t = \frac{T}{2} \cdot \frac{(V\text{-}Vg)}{(\ V\ )} \quad (2)$$

It is apparent that for a positive audio signal the highway opens a moment Δt earlier than T/2, and similarly, for a negative signal, a moment Δt later. This has been demonstrated in Figures 4B and 4C. This time Δt multiplied by the constant α will give the audio signal over capacitor C_2. In Figure 6, this time Δt is represented by line CF; the following derivation will express the time Δt as function of the signal Vg.

$$BC = \frac{FC}{\tan\angle CBF} = \frac{\Delta t}{\frac{\frac{1}{2}T}{\frac{1}{2}V}}$$

$$EC = \frac{FC}{\tan\angle CEF} = \frac{\Delta t}{\frac{\frac{1}{2}T}{\frac{1}{2}V}}$$

$$BC + EC = Vg = \frac{2\,\Delta t \cdot V}{T}$$

$$\text{or } \Delta t = \frac{Vg}{V} \cdot \frac{T}{2} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

The audio information over $C_2 = Vc_2$

$$Vc_2 = \alpha\Delta t = \frac{Vg \cdot \alpha T}{2V} = \frac{Vg}{2} \quad (4)$$

Equation (4) states that only half of the sample over C_1 has been received on the link side of the highway.

We will now show how the addition of a sawtooth signal in series with the highway will enlarge the moment Δt.

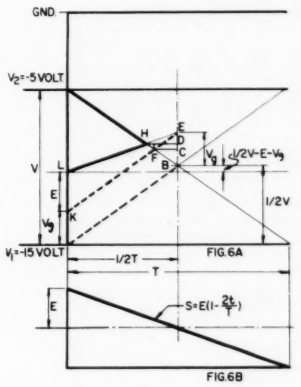

Figure 6(A). ΔtE as Function of Audio Plus Sawtooth Signal

Figure 6(B). Sawtooth Signal as Function of T.

When no modulation is present the highway will still open at a time $t = \frac{1}{2}T$. This might be seen as follows:

The sawtooth can analytically be represented by:

$$E(t) = E\left(1 - \frac{2t}{T}\right) \quad . \quad . \quad . \quad \text{(Figure 6B)}$$

The highway opens when:

$$V_1 + \alpha t + E\left(1 - \frac{2t}{T}\right) = V_2 - \alpha t$$
$$t\left(2\alpha - \frac{2E}{T}\right) = V\text{-}E$$
$$t = \frac{V\text{-}E}{2\alpha\,T\text{-}2E} \cdot T$$
$$\text{or } t = \tfrac{1}{2}T$$

When an audio signal is now appplied over C_1 a similar action will take place to that previously described; i.e., a positive signal will open the highway earlier, a negative one later. However, the time Δt_E has been changed, and from Figure 6 it can be concluded that the time Δt_E is also a function of the sawtooth with amplitude 2E.

The time Δt_E is represented in Figure 6 by the line HD and an expression can be found which gives Δt_E as function of E and Vg:

$$BD = \frac{HD}{\tan\angle DBH} = \frac{\Delta t_E}{\frac{1}{2}T / \frac{1}{2}V}$$

$$DE = \frac{HD}{\tan\angle DEH} = \frac{\Delta t_E}{\frac{1}{2}T / \frac{1}{2}V\text{-}E}$$

$$BD + DE = Vg = \frac{\Delta t_E\,((V\text{-}2E)}{T} + \frac{\Delta t_E \cdot V}{T}$$

$$Vg = \frac{\Delta t_E\,(2V\text{-}2E)}{T}$$

$$\text{or } \Delta t_E = \frac{Vg}{V\text{-}E} \cdot \frac{T}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

The audio information over $C_2 = Vc_2$

$$Vc_2 = \alpha \Delta t_E = \frac{Vg\alpha T}{2(V\text{-}E)}$$

$$\text{or } Vc_2 = \frac{V}{2(V\text{-}E)}\,Vg \quad . \quad . \quad . \quad (6)$$

Conclusion from (6):

When $2(V\text{-}E) = V$ or $E = \frac{1}{2}V$ the sample Vg will be transmitted without loss. Voltage ratio $\frac{Vc_2}{Vg} = \frac{V}{2(V\text{-}E)}$ represents the gain.

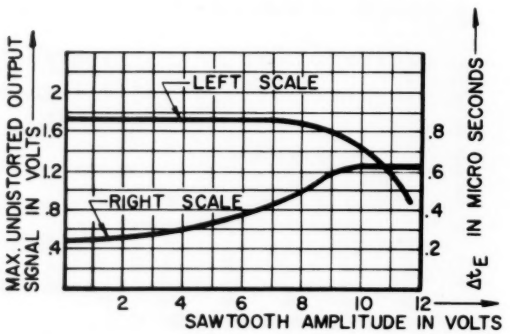

Figure 7. Undistorted Audio Output Level as a Function of the Sawtooth Signal

Equation (6) indicates that when $\frac{1}{2}V < E < V$ the sample will be amplified. When E approaches V, or is equal to V, the circuit will become unstable. The gain is naturally very attractive, but there is another condition which limits the maximum gain. This might be seen from equation (5). It is apparent that the maximum swing Δt_E max $= \frac{1}{2}T$, hence the maximum sample amplitude over capacitor C_2 is:

$$Vg_{\max} = V\text{-}E. \quad (7)$$

In Figure 7, Δt_E max. has been plotted as a function of the sawtooth amplitude. Without sawtooth Δt_E max. = 0.25 microseconds. Hence, from equation (3) it can be concluded that the maximum signal is $\frac{1}{2}V$ and therefore a large sawtooth signal will limit the maximum signal. In Figure 7, this maximum signal has been plotted as a function of the sawtooth amplitude.

Equation (6) can be used to calculate the gain of the sample. To recover the audio, a sample loss will be introduced. This loss amounts to approximately 4½ db (see reference 1). Beside this loss another phenomenon has to be considered — i.e., time constant, which actually effects the factor V. By taking these effects into consideration the gain can be calculated. The results have been shown in Figure 8; the dotted line shows the calculated values, the solid line the actual measured values.

Before discussing the complete transmission path through the switchboard, it will be worthwhile to first describe the circuitry in some detail. The whole transmission circuitry may be divided into three parts:

1. Line Circuit
2. Common Transmission Control
3. Link Circuit

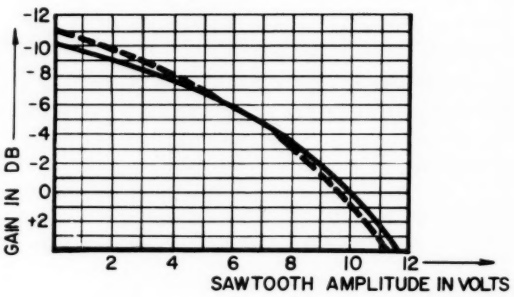

Figure 8. Gain as Function of the Sawtooth Amplitude

Line Circuit

The line circuit has several functions to perform:

a. d.c. and ringing supply
b. Loop, seizure, answering, ringing and busy supervision
c. Dialing
d. Release
e. Impedance matching

Functions (a) through (d) will be referred to as the supervisory control; this circuitry is physically separated from function (e) by a transformer T1

(see Figure 14). The transmission aspects of the supervisory control are not significant; therefore only the impedance converter and the line gate will be discussed in detail. The line circuit (Figure 9) has two functions to perform—i.e., sending and receiving.

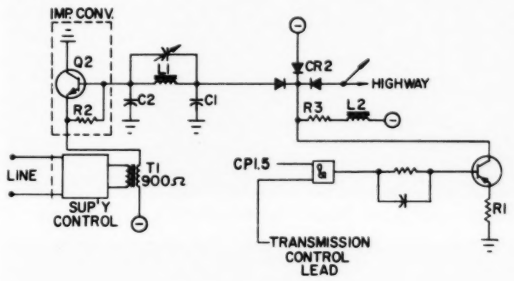

Figure 9. Line Circuit

Sending

Assume a connection between 2 subscribers has been established, and that the sending subscriber is assigned to multiplex pulse cp-1.5n and the receiving party to multiplex cp-1.5$_{n+1}$.

Every 80 microseconds, the cp-1.5n will open the "and" gate of the sending subset, turning on the switching transistor Q_1 which charges capacitor C_1 (see Figure 3). The audio information of the sending subscriber (appearing over the secondary of transformer T_1) by-passes the impedance converter through resistor R_2 and via the low-pass filter the audio will be introduced on the capacitor C_1, where it will be sampled by the multiplex pulse cp-1.5n.

Receiving

Audio information imposed on the multiplex pulse will be demodulated by an RC filter. The R component is produced by the impedance converter, which steps up the line impedance from approximately 900 ohms to 15,000 ohms. This high impedance is necessary since the repetition rate of the multiplex pulses is approximately 80 microseconds; therefore a time constant of $<$ 80 microseconds is required to get sufficient demodulation. The switching frequencies, especially the 12½ kilocycles, are suppressed by the low-pass filter; thus plain audio will appear at the base of the impedance converter, which transforms the high impedance level down to the line impedance.

The performance of the impedance converter as a function of the dynamic β of transistor Q_2 is demonstrated in Figures 10A and 10B. Figure 10A shows the emitter impedance and insertion loss in the sending direction; Figure 10B shows base impedance and insertion loss in the receiving direction.

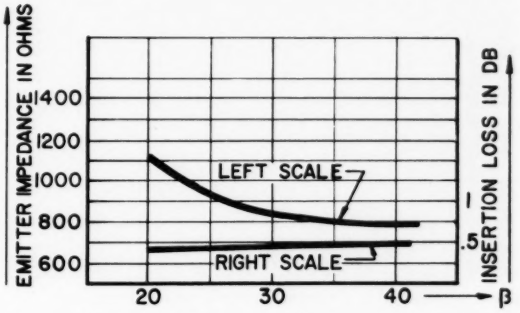

Figure 10A. Emitter Impedance and Insertion Loss of the Impedance Converter as a Function of the Dynamic β

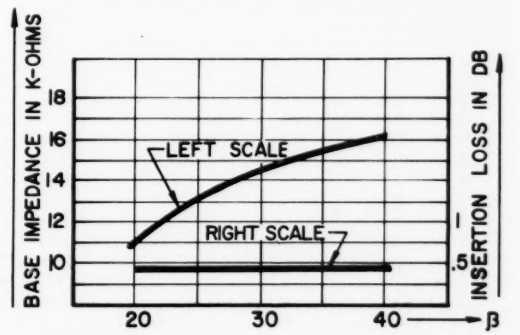

Figure 10B. Base Impedance and Insertion Loss of the Impedance Converter as Function of the Dynamic β

Controls

Common Transmission

The highway is formed actually by two transformers T_1 and T_2 as shown in Figure 11. Transformer T_1 injects the sawtooth signal in series with the highway; T_2 is used to sense equal potentials at capacitors C_1 and C_2 in the line and link gates (Figure 3). The sawtooth signal is obtained as follows: the cp-0.5 pulse is applied to the base of Q_1 and turns the transistor on during this 0.5 microsecond period. Since the inductance L_1 forms a high impedance for the fast-changing collector current, practically all the current will be used to charge capacitor C_1. After the clock pulse is over, capacitor C_1 has 1.5 microseconds time to discharge over inductance L_1 before the next clock pulse appears. With variable resistance R_1 the collector current, and thus the amplitude of the sawtooth signal, can be varied. The generated sawtooth signal is led to the base of an emitter-follower Q_2 operating in Class A, which supplies sufficient current for driving the sawtooth transformer T_1.

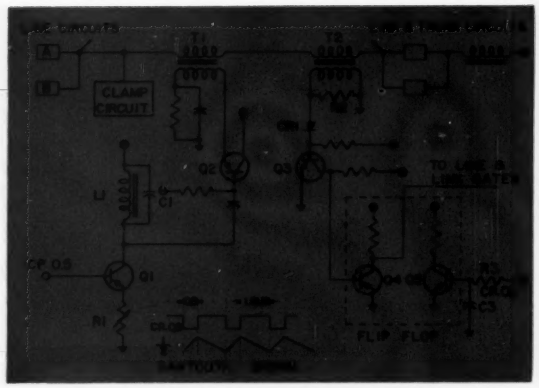

Figure 11. Common Transmission Control Circuit

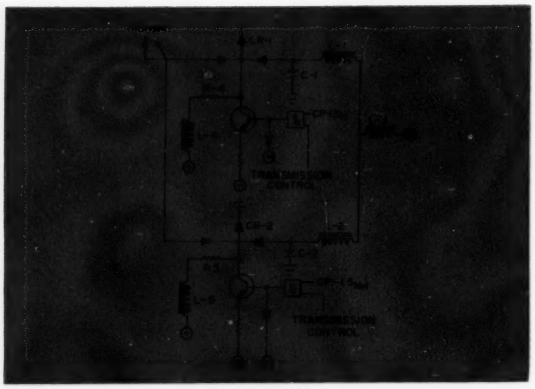

Figure 13. Link Circuit

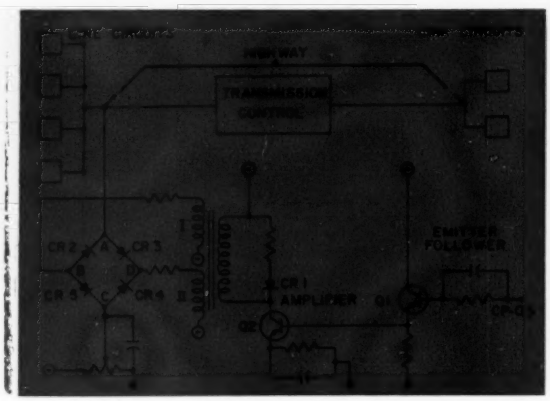

Figure 12. Highway Clamping Circuit

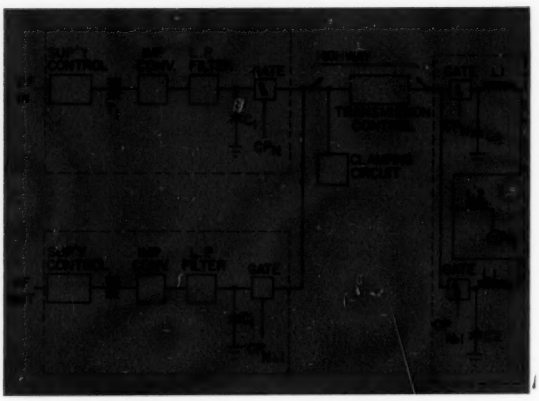

Figure 14. Complete Connection

Transmission

The small current through T_2 indicates that there is equilibrium, and causes a voltage drop over R_2. This signal will turn off transistor Q_3 so that sufficient signal is obtained to trigger the flip-flop. The silicon diode CR_1 is necessary to avoid triggering by an extraneous signal; the proper signal has sufficient magnitude to overcome this threshold of approximately 0.6V.

When the flip-flop triggers, collector of Q_4 will be at ground, thus closing the occupied line and link gates. After each multiplex pulse, the flip-flop is reset by the cp-0.5 pulse. The integrating network of R_3 and C_3 is used to modify the rectangular clock pulse into a triangular shape so that this signal actually gets a longer rise time. This time delay is used to reset the flip-flop somewhat later, which gives some improvement of the circuit operation.

Highway Clamping

The highway is reactive; inherently it can hold the stored information longer than a multiplex period, resulting in crosstalk. This unwanted residual can be reduced considerably by clamping the highway to a fixed reference voltage between multiplex pulses. The cp-0.5 pulse falls in this guard period; therefore, good use of this clock pulse can be made. To minimize the clock load, an emitter follower Q_1 is used to drive pulse-amplifier Q_2.

The purpose of CR_1 is to cut off the undershoot of the positive pulse that appears over the primary of the pulse transformer. Secondary winding I (Figure 12) supplies a negative 15v pulse to point B, and winding II a positive 15v pulse to point D of a bridge consisting of 4 diodes. Point C is biased to approximately —10v; point A is connected to the line side of the highway.

During operation the highway potential varies from —7v to —13v. Assume that the highway at some time has a potential of —13v. Initially point B is at —5v and point D at approximately —15v. During the clock pulse, point B will go towards —20v, but as soon as B reaches —10v, CR_5 will

conduct, which in turn will cause CR_2 to conduct, and therefore the highway will be clamped to —10v. Similarly it can be shown that when the highway has a —7v potential, diodes CR_3 and CR_4 will conduct and again the highway will be clamped to approximately —10v.

Link

This circuit (see Figure 13) consists mainly of two identical link gates. In the link, the calling and called party, which are in different time slots, will be audio coupled. The link gate, actually a mirror image of the line gate, is very similar in operation.

An impedance converter is not necessary, since the audio information which is carried by the cp-1.5n pulse is demodulated and directly modulated again on the cp-1.5_{n+1} pulse, which sends this information back over the highway to the line gate assigned to the called subscriber. For coupling, an inductance L_3 is used. This inductance must have a large impedance since it is shunting the high filter impedance (15,000 ohms). However, for a trunk call an impedance converter is required. A trunk consists primarily of a link gate, impedance converter, and some supervisory control equipment.

Block Diagram

A complete block diagram of a transmission path through the switchboard is shown in Figure 14 and is self-explanatory. However, a few remarks may be added:

1. Only one highway is used for a complete loop.
2. The two parties are separated by time (adjacent multiplex pulses).
3. The two subscribers are coupled in the link.
4. There are provisions for incoming as well as outgoing trunks.

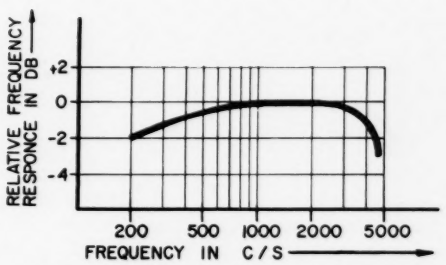

Figure 15. Relative Frequency Response of a Complete Connection

Conclusions

Several laboratory models of this lossless transmission circuit have been built and tested and the results have been very encouraging. Figure 15 shows the relative frequency response of a connection between two subscribers. The total harmonic distortion, measured at the output, for a 1000-cycles-per-second signal at zero dbm level is approximately 2%. The demodulation products in the output are more than 50 db below the wanted signal level.

A complete P-A-B-X has been constructed, and the system performance is being evaluated with reference to crosstalk, and idle channel noise; no evidence to date has indicated any significant problems.

Currently, investigations are in progress which will determine the applications of this transmission circuit for larger systems.

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